Global Joint Conference on Industrial Engineering and Its Application Areas - 2016

14 - 15 July 2016
Elite World Istanbul Hotel

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ISBN: 978-605-62699-6-7

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016

14 - 15 July 2016

Elite World Istanbul Hotel

Istanbul - Turkey

Editors:

Fethi Calisir

Murat Durucu

ISBN: 978-605-62699-6-7

GJCIE 2016

Global Joint Conference on Industrial Engineering and Its Application Areas

14 – 15 July 2016 – Istanbul, Turkey

"Building Successful University-Industry Alliances"

Welcome Message from Conference Chair

Fethi CALISIR, PhD

Dean, Management Faculty

Istanbul Technical University, TURKEY

On behalf of the Global Joint Conference on Industrial Engineering and Its Application Areas (GJCIE 2016) Organizing Committee, I welcome you to the GJCIE 2016 in Istanbul, Turkey. The GJCIE 2016 is composed of three co-located conferences: the 1st Global Conference on Industrial Engineering (GCIE), the 3rd Global Conference on Engineering and Technology Management (GCETM), and the 2nd Global Conference on Healthcare Systems Engineering and Management (GCHSEM). The GGJCIE 2016 will be an internationally renowned forum for researchers, practitioners, and educators to present and discuss the most recent innovations, trends, experiences, and challenges in the field of industrial engineering. It will bring together experts from academia and industry to exchange the latest research results and trends, and their practical applications in the aforementioned areas of industrial engineering. This will be accomplished through the following three modes of communication: keynote presentations, parallel sessions, and poster sessions.

Alliances between universities and industries are growing because of increasing demand for innovation, rising global competitiveness, and declining government support for research and development. However, a big majority of such partnerships do not succeed and terminate with little or no benefits to either party. This conference will shed light on industrial engineering techniques and practices that may help organizations and universities in their quest to build successful university – industry alliances. We have a great program and fantastic keynote speakers this year.

The GJCIE 2016 will take place from July 14th to July 15th at the Elite World Istanbul Hotel in Istanbul, Turkey. Istanbul is the only city in the world built on two continents. Its rich history has given it a multitude of museums, historical buildings and mosques, Byzantine churches and Roman aqueducts. This exciting venue is alive with the hustle and bustle of business and trade which for centuries has made it a vital trading hub between east and west. Straddling Europe and Asia, Istanbul is the largest and most monumental city in Turkey. It is a melting pot of cultures which mix harmoniously on both sides of a city that is split geographically by the Bosphorus strait. This bustling city is home to over 13 million people and from 14 to 15 July 2016 will also be home to the GJCIE 2016.

I would like to welcome you to the GJCIE 2016 and wish you a wonderful time in Istanbul!

Best regards,

FETHI CALISIR, Ph.D.

Conference Chair

Keynote Speech – I

Krishnaswami Srihari, PhD

- Executive Vice Provost for International Initiatives and Chief Global Officer
- Dean and SUNY Distinguished Professor – Thomas J. Watson School of Engineering and Applied Science
  Binghamton University – State University of New York, USA

14 July 2016 – Room: Galata

Engineering Education in a Global World

Abstract

Tomorrow’s engineering graduates are going to work and thrive in a world that is far more globalized than what we are used to today. An engineer, who graduates with a bachelor’s degree in 2020, will be mid-career in 2045 (or thereabouts). This engineer is going to work and succeed in a world that knows no intellectual boundaries, wherein working across national boundaries is going to be an absolute necessity.

Even today, the design, manufacture and sales of engineering products often requires effective global partnerships. This extends to the services industry also. Over the past decade (or so), the need for effective global partnerships has only increased. The increased use of the internet combined with enhanced communications has resulted in engineers working in a global marketplace. As a result, our graduates need to have the global and cultural competency to work with colleagues around the world. It is under this framework and context that today’s leading universities are working hard to initiate, develop and sustain robust academic partnerships with other institutions across the globe. These academic partnerships enhance our students’ educational experience while concurrently initiating and cultivating research initiatives along with active idea exchange. In addition, in today’s global world, international experiences enhance a student’s employability, help to develop soft skills, enhance cultural understanding, and are a testament to one’s adaptability.

Today, there are several effective models of international collaboration that actively and effectively incorporate students, staff and faculty. These models and their associated strategies address the needs of the academic spectrum ranging from freshmen through doctoral students, faculty, staff, and academic (campus) leaders. Examples range include (but are not limited to) traditional study abroad (and exchange) programs to international internships to combined curriculum (undergraduate and graduate programs), collaborative research endeavors, and joint (international) centers. In each case, substantial benefits accrue to both the individual (engineer) and the participating academic institutions.

It is true that the design and implementation of comprehensive international programs requires substantial investment in the form of time and monetary resources. However, the outcomes always include memorable experiences that bond and rally students and alumni to the programs and services provided by their alma mater. The invaluable impact on the academic experience of a student cannot be overstated. Besides, international experience is becoming a necessity for successful faculty members while active and effective international programs are today a hallmark of a successful university.

KEYNOTE SPEECH – II

DURSUN DELEN, PHD

- Director of Research—Center for Health Systems Innovation, Spears and Patterson Endowed Chairs in Business Analytics
- Professor of Management Science and Information Systems, Spears School of Business, Oklahoma State University

15 JULY 2016 – ROOM: GALATA

DEMYSTIFYING BIG DATA AND ANALYTICS WITH REAL WORLD APPLICATIONS

ABSTRACT

Business analytics, big data, business intelligence, data science—relatively new terms/buzzwords—are gaining popularity in the business world like nothing else that we have witnessed in recent history. Although named differently, these terms seem to have a common theme, in fact most people considers them as synonyms. Generally speaking, analytics is the art and science of extracting/discovering insight—by way of using sophisticated mathematical/statistical models along with a variety of data and expert knowledge—to support accurate and timely decision making. In a sense, analytics is all about decision making and problem solving. These days, analytics can be defined as simply as “the discovery of meaningful patterns in data.” In this era of abundant data, analytics tends to be used on large quantities and varieties of data that we conveniently labeled as “Big Data.”

Big data and business analytics are a couple of catchphrases one would commonly hear/see in business, science and education circles nowadays. No matter what technical journal or magazine you look at, it is very likely that you will see articles about big data and business analytics and how they are changing the way managerial decisions are being made. Big data analytics (or simply analytics) has become a new label for evidence-based management (i.e., evidence/data-driven decision making). But why has analytics become so popular? Why now? Is it something new/novel? Why there are so many different labels and definitions for it? This presentation will attempt to answer these questions, and by doing so, will demystify the underlying terms/concepts of analytics with real-world application cases ranging from healthcare to medicine, entertainment to education.

14 July 2016, Thursday

09:00 - 16:00	Registration

09:30 - 09:40	Welcome Address by Fethi Calisir
Room: Galata	

09:40 - 10:40 Keynote Session - I

Room: Galata

Krishnaswami Srihari, PhD

- Executive Vice Provost for International Initiatives and Chief Global Officer
- Dean and SUNY Distinguished Professor – Thomas J. Watson School of Engineering and Applied Science
  Binghamton University – State University of New York, USA

Title: "Engineering Education in a Global World"

10:40 - 11:10	Break - Galata Fuaye

11:10 - 12:30 Parallel Session - I

Room: Ayasofya — Chair: Gulsah Hancerliogullari

ID: 26	Understanding Facebook Usage of Undergraduate Students in Turkey	Ecem Basak (Istanbul Technical University) Fethi Calisir (Istanbul Technical University)
ID: 69	A Framework to Assign Forklift Drivers to Relevant Duties Based on Physical and Cognitive Factors	Firat Ozkan (Eskisehir Osmangazi University) Berna Ulutas (Eskisehir Osmangazi University)
ID: 93	Ergonomic Assessment of Hand Tool Design to Reduce Occupational Accidents	Orhan Korhan (Eastern Mediterranean University) Mohammad Yazdi (Eastern Mediterranean University)
ID: 95	An Estimation of Anthropometric Measures of Adult Male Population of Anatolia	Mahmut Eksioglu (Bogazici University) Elif Eren (Bogazici University)

11:10 - 12:30	Parallel Session - II	
Room: Rumeli	Chair: Oguzhan Erdinc	
ID: 15	An Empirical Study of Safety Improvement by Risk Management Guidance in Healthcare Organisations	Mecit Can Emre Simsekler (University College London) Bilal Gokpinar (University College London)
ID: 27	Risk Management in Hospital Settings: Understanding and Improving the Current Practice	Gulsum Kubra Kaya (University of Cambridge) Halime Tuba Canbaz (Necmettin Erbakan University) Mecit Can Emre Simsekler (University College London) James Ward (University of Cambridge) John Clarkson (University of Cambridge)
ID: 89	A System Dynamics Model of Medication Waste Problems in the Saudi Arabian Healthcare System	Faisal A Alkhaldi (Tennessee Technological University)
ID: 121	Evaluation of Risk Management Practices: Data Analysis of NHS England Hospitals	Gulsum Kubra Kaya (University of Cambridge) Halime Tuba Canbaz (Necmettin Erbakan University) James Ward (University of Cambridge) John Clarkson (University of Cambridge)

11:10 - 12:30	Parallel Session - III	
Room: Pier Loti	Chair: Emre Cevikcan	
ID: 42	Operators' Assignment in Cellular Manufacturing Systems: A Review of Recent Applications	Yeliz Buruk Sahin (Eskisehir Osmangazi University) Serafettin Alpay (Eskisehir Osmangazi University)
ID: 88	Role of Entrepreneur Orientation on Employee Work Outcomes	Gaye Karacay Aydin (Istanbul Technical University) Efe Eris (Istanbul Technical University)
ID: 111	Minimizing Total Earliness Subject to Minimum Number of Cells and n_T=0	Gursel A. Suer (Ohio University) Casey Davis (Ohio University) Kyle Good (Ohio University)
ID: 140	Factors Effecting Job Satisfaction in Pharmaceutical Industry: A Turkish Company Application	Cahit Ali Bayraktar (Istanbul Technical University) Murat Durucu (Istanbul Technical University)

12:30 - 13:30	Lunch Break - Elite Restaurant

13:30 - 14:30	Parallel Session - IV	
Room: Ayasofya	**Chair: Reza Tavakkoli-Moghaddam**	
ID: 21	The Impacts of Economic Sanctions on Supply Chain Management: Empirical Analysis of Iranian Supply Chains	Ehsan Shakeri (Eastern Mediterranean University) Bela Vizvari (Eastern Mediterranean University) Ramtin Nazerian (Eastern Mediterranean University)
ID: 62	A Particle Swarm Optimization Algorithm for Integrated Forward-Reverse Supply Chain Network Decisions	Seval Ene (Uludag University) Nursel Ozturk (Uludag University)
ID: 78	Collision and Conflict-Free Airport Ground-Traffic Management	Ali Akgunduz (Concordia University)

13:30 - 14:30	Parallel Session - V	
Room: Rumeli	**Chair: Hatice Camgoz Akdag**	
ID: 13	Wind Farm Layout Optimization to Reduce Noise	Esma Sedef Kara (Eastern Mediterranean University) Orhan Korhan (Eastern Mediterranean University) Huseyin Guden (Eastern Mediterranean University)
ID: 30	A Simulation Model to Evaluate Treatment Services Reconfigurations for Patients with Parkinson's Disease	Reda M. Lebcir (University of Hertfordshire) Eren Demir (University of Hertfordshire) Tahar Boukhobza (University of Algiers) David Southern (Pathways Communications Ltd)
ID: 87	Prioritized Scheduling and Routing for Home Healthcare Services	Ahmet Cinar (Koc University) F. Sibel Salman (Koc University) Burcin Bozkaya (Sabanci University)

13:30 - 14:30	Parallel Session - VI	
Room: Pier Loti	**Chair: Mecit Can Emre Simsekler**	
ID: 16	Heuristic Evaluation: Overview and a Proposed Framework with User Experience Perspective	Oguzhan Erdinc (Turkish Air Force Academy)
ID: 35	The Effects of Knowledge Sharing and Types of Learning on Individual Creativity: A Structural Equation Model	Gozde Kadioglu (Istanbul Technical University) Beril Gul (Istanbul Technical University) Ayberk Soyer (Istanbul Technical University) Umut Asan (Istanbul Technical University)
ID: 67	The Factors Affecting Knowledge Transfer between Individuals in Organizations	Omer Faruk Gurcan (Istanbul Technical University) Cigdem Altin Gumussoy (Istanbul Technical University)

14:40 - 15:40	Parallel Session - VII	
Room: Ayasofya	Chair: Orhan Korhan	
ID: 63	Network Design for Closed Loop Supply Chains Using Multi-Objective Optimization Model	Seval Ene (Uludag University) Nursel Ozturk (Uludag University)
ID: 107	Volume Flexibility in Robust Design of Supply Flow under Operational and Disruption Risks	Alireza Ebrahim Nejad (Concordia University) Onur Kuzgunkaya (Concordia University)
ID: 117	A New Methodology for Solving Real Time Quay Crane Scheduling Problem	Aybuke Alper (Pamukkale University) Mustafa Egemen Taner (Pamukkale University) Osman Kulak (Pamukkale University) Yusuf Yilmaz (Pamukkale University)

14:40 - 15:40	Parallel Session - VIII	
Room: Rumeli	Chair: Reda M. Lebcir	
ID: 36	A Computer-Aided Grading System for Clinical Evaluation of Dry Eye Syndrome	Ayse Arslan (Yildirim Beyazit University) Baha Sen (Yildirim Beyazit University) Dursun Delen (Oklohama State University) Betul Seher Uysal (Ataturk Education and Research Hospital) Fatih Vehbi Celebi (Yildirim Beyazit University) Hasan Basri Cakmak (Hacettepe University Hospital)
ID: 60	Integrated Consumption and Provision Map Implementation in Healthcare Sector	Nurcan Deniz (Eskisehir Osmangazi University) Feristah Ozcelik (Eskisehir Osmangazi University)
ID: 84	Implementation of Computer Assisted Voice Search Engine for Medical Transcription	Ayse Arslan (Yildirim Beyazit University) Baha Sen (Yildirim Beyazit University) Dursun Delen (Oklohama State University) Fatih Vehbi Celebi (Yildirim Beyazit University)

14:40 - 15:40	Parallel Session - IX	
Room: Pier Loti	Chair: Fetih Yildirim	
ID: 32	A Timetabling Approach: Optimal Exam Schedule in a University	Gulsah Hancerliogullari (Istanbul Technical University) Miray Gurmen (Istanbul Bilgi University) Onur Akdeniz (Istanbul Bilgi University) Emrah Koksalmis (Istanbul Technical University)
ID: 92	A Genetic Algorithm for the P-Median Facility Location Problem	Mehmet Kursat Oksuz (Istanbul Technical University) Sule Itir Satoglu (Istanbul Technical University) Gulgun Kayakutlu (Istanbul Technical University) Kadir Buyukozkan (Karadeniz Technical University)
ID: 125	MIP Model and Hybrid Heuristic Solution Method for Milkrun	Duygu Yilmaz Eroglu (Uludag University)

15:40 - 16:10	Break - Galata Fuaye

16:10 - 17:30	Parallel Session - X	
Room: Ayasofya	Chair: Onur Kuzgunkaya	
ID: 52	Performance Analysis of Meta-heuristic Algorithms for a Quadratic Assignment Problem	Zohreh Raziei (University of Tehran) Reza Tavakkoli-Moghaddam (University of Tehran) Siavash Tabrizian (Sharif University of Technology)
ID: 55	A Tri-Level r-Interdiction Median Model for a Hierarchical Facilities Location Problem	Maryam Akbari-Jafarabadi (University of Science and Technology of Mazandaran) Mehdi Mahmoodjanloo (University of Science and Technology of Mazandaran) Reza Tavakkoli-Moghaddam (University of Tehran)
ID: 71	Coral Reefs Optimization Algorithm's Suitability for Dynamic Cell Formation Problem	Nurcan Deniz (Eskisehir Osmangazi University) Feristah Ozcelik (Eskisehir Osmangazi University)
ID: 122	Dynamic Scheduling of Generalized Flowshop Problems Using Mathematical Programming	Burcu Caglar Gencosman (Uludag University) Duygu Yilmaz Eroglu (Uludag University)

16:10 - 17:30	Parallel Session - XI	
Room: Rumeli	Chair: Mahmut Eksioglu	
ID: 43	An Optimization Approach for Balancing Multi Model Walking-Worker Assembly Systems	Peiman Alipour Sarvari (Istanbul Technical University) Emre Cevikcan (Istanbul Technical University)
ID: 49	Assessment of 5S and Overall Equipment Effectiveness Contributions Towards Promoting Total Productive Maintenance Implementation	Abdullatif Ben Hassan (University of Windsor) Walid Abdul-Kader (University of Windsor)
ID: 72	Event Driven Dynamic Job Shop Scheduling Under Capacity Constraints	Adil Baykasoglu (Dokuz Eylul University) Fatma Selen Karaslan (Dokuz Eylul University)
ID: 48	Multi-factor Frameworks and Models for Innovation Risk Management	Kerron O. Boothe (Karlsruhe Institute of Technology)

16:10 - 17:30	Parallel Session - XII	
Room: Pier Loti		Chair: Gaye Karacay Aydin
ID: 53	Statistical Estimation and Test of Hypothesis with a Weibull Distribution: Applications to Industrial Lifetime Data	Fetih Yildirim (Cankaya University) M. Qamarul Islam (Cankaya University)
ID: 61	Reliability Analysis of Product Fleets in Use Phase: Risk Detection and Prognosis Based on Data Logger	Stefan Bracke (University Wuppertal)
ID: 91	Wireless Multimedia Sensor Network Reliability Analysis with Petri Nets	Omer Ozkan (Turkish Air Force Academy) Murat Ermis (Turkish Air Force Academy) Ilker Bekmezci (Turkish Air Force Academy)
ID: 110	Simulation Based Optimization of Stock Levels for Maintenance Logistics with Multi-Skill Parallel Servers	Andrei Sleptchenko (Qatar University) Hasan H. Turan (Qatar University) Shaligram Pokharel (Qatar University) Tarek Y. ElMekkawy (Qatar University)

18:00 - 20:00	Welcome Reception - Beylerbeyi

15 July 2016, Friday

09:00 - 16:00	Registration

09:40 - 10:40 Keynote Session II

Room: Galata

Dursun Delen, PhD

- Director of Research—Center for Health Systems Innovation, Spears and Patterson Endowed Chairs in Business Analytics
- Professor of Management Science and Information Systems, Spears School of Business, Oklahoma State University

Title: "Demystifying Big Data and Analytics with Real World Applications"

10:40 - 11:10	Break - Galata Fuaye

11:10 - 12:30 Parallel Session - XIII

Room: Ayasofya — Chair: Levent Atahan

ID: 66	A Decomposition Method to Solve a Game Based Multi-Objective Model for a Scheduling Problem at a Chemotherapy Center under Uncertainty	Javad Ansarifar (University of Tehran) Reza Tavakkoli-Moghaddam (University of Tehran) Faezeh Akhavizadegan (University of Tehran)
ID: 77	Vehicle Routing Problem in Omni-Channel Retail Distribution	Tarek Y. ElMekkawy (Qatar University) Mohamed M.S. Abdulkader (University of Manitoba) Yuvraj Gajpal (University of Manitoba)
ID: 109	Fire Scheduling Problem with Probability of Hit Time Window	Sezgin Kaplan (Turkish Air Force Academy)
ID: 123	Comparison of Dynamic Scheduling Approaches: Predictive/Reactive Scheduling vs. Robust Proactive Scheduling in a Generalized Flowshop Environment	Burcu Caglar Gencosman (Uludag University) Duygu Yilmaz Eroglu (Uludag University)

11:10 - 12:30	Parallel Session - XIV	
Room: Rumeli	Chair: Jung Keun Lee	
ID: 19	Analysis and Validation of Several Emission Models for Automobiles Using Real-Time Data	Ahmet Gurcan Capraz (Fatih University) Pinar Ozel (Fatih University) Mehmet Sevkli (Fatih University)
ID: 41	Literature Review on Modelling, Analysis and Planning of Emergency Evacuation Process For Public Marine Transportation	Peiman Alipour Sarvari (Istanbul Technical University) Emre Cevikcan (Istanbul Technical University) Alp Ustundag (Istanbul Technical University)
ID: 81	Strategic Alignment and Technology Management in FNSS	Kivilcim Ersoy (FNSS)
ID: 82	TOGAF Based Governance Framework Proposition for Technology Management Systems	Nermin Sokmen (The Scientific and Technological Research Council of Turkey - TUBITAK)

11:10 - 12:30	Parallel Session - XV	
Room: Pier Loti	Chair: Ercan Hoskara	
ID: 11	Determining the Optimum Number of Trucks in Pavement Process	Mohammed Al Mohsin (University of Buraimi) Bevian Al Hadithi (University of Technology) Ali Alnuaimi (Sultan Qaboos University)
ID: 39	Customer Profiling for Co-creation in Global New Product Development	Ilhami Burak Safran (Ondokuz Mayis University) Koray Altun (Bursa Technical University) Turkay Dereli (Iskenderun Technical University)
ID: 40	A New Mathematical Model towards the Integration of Cell Formation and Part Scheduling	Yeliz Buruk Sahin (Eskisehir Osmangazi University) Serafettin Alpay (Eskisehir Osmangazi University)
ID: 54	Cooperation Networks Types and Intensity: Descriptive Analysis of Turkish SMEs	Eyup Calik (Yalova University) Fethi Calisir (Istanbul Technical University)

12:30 - 13:30	Lunch Break - Elite Restaurant

13:30 - 14:30	Parallel Session - XVI	
Room: Ayasofya	Chair: Kivilcim Ersoy	
ID: 17	Pessimistic Supply Chain Efficiency Evaluation	Mustapha D. Ibrahim (Eastern Mediterranean University) Sahand Daneshvar (Eastern Mediterranean University)
ID: 37	Sustainability Effect on Optimum Stock Keeping Unit Variety and Profit	Ilkan Sarigol (Yildiz Technical University) Coskun Ozkan (Yildiz Technical University)
ID: 83	A Strategic Supply Chain Network Design Evaluation Based on Mixed-Integer Linear Programming	Peiman Alipour Sarvari (Istanbul Technical University) Alp Ustundag (Istanbul Technical University) Emre Cevikcan (Istanbul Technical University)

13:30 - 14:30	Parallel Session - XVII	
Room: Rumeli	Chair: Abdullatif Ben Hassan	
ID: 12	Effect of Supplier's Assessment on Waste Prevention	Nasim Sadegh (Eastern Mediterranean University) Orhan Korhan (Eastern Mediterranean University) Ramtin Nazerian (Eastern Mediterranean University)
ID: 22	Solving a New Multi-objective Multiple Allocation Hub Covering Location Problem with a Ring-Structured Hub Network by the NSGA-II	Maryam Eghbali-Zarch (University of Tehran) Reza Tavakkoli-Moghaddam (University of Tehran) Kazem Dehghan-Sanej (Islamic Azad University)
ID: 57	Three Meta-Heuristic Algorithms for Efficient Truck-Door Assignment and Product Placement Plans in Cross-Docking Centers	Ilker Kucukoglu (Uludag University) Nursel Ozturk (Uludag University)

13:30 - 14:30	Parallel Session - XVIII	
Room: Pier Loti	Chair: Gursel Suer	
ID: 23	A Parallel Kalman Filter for Estimation of Human Body Segment Orientation Using Wearable IMMU	Jung Keun Lee (Hankyong National University)
ID: 47	The Impact of Musculoskeletal Discomfort on Tablet-assisted Education System	Elif Binboga Yel (Girne American University) Banu Numan Uyal (Eastern Mediterranean University) Orhan Korhan (Eastern Mediterranean University)
ID: 139	The Human Physical and Cognitive Roles in Automation Systems	Behice Durgun (Cukurova University)

14:40 - 15:40	Parallel Session - XIX	
Room: Ayasofya	Chair: Gulsum Kubra Kaya	
ID: 104	GSCM for Construction Waste Management in Green Building Operations	Hatice Camgoz Akdag (Istanbul Technical University) Ercan Hoskara (Eastern Mediterranean University) Tugce Beldek (Istanbul Technical University)
ID: 113	Alternative Global Supply Chain Design Strategies for A Blood Sugar Strip Manufacturer Considering Layered Cellular Design	Jue Jiang (Ohio University) Gursel A. Suer (Ohio University)
ID: 118	Various Scenario Analyses for Yard Crane Scheduling Problem	Mustafa Egemen Taner (Pamukkale University) Osman Kulak (Pamukkale University) Yusuf Yilmaz (Pamukkale University) Aybuke Alper (Pamukkale University)

14:40 - 15:40	Parallel Session - XX	
Room: Rumeli	Chair: Mehmet Gumus	
ID: 29	Analysis of Interactions among the Lean Implementation Barriers	Saliha Karadayi Usta (Istanbul Technical University) Seyda Serdar Asan (Istanbul Technical University)
ID: 56	Hybrid and Intelligent Price Forecasting Using Product Specifications	Ipek Kivanc (Istanbul Technical University) Ayca Altay (Istanbul Technical University)
ID: 127	Genetic Algorithm Based Hybrid Solution for Feature Selection	Duygu Yilmaz Eroglu (Uludag University) Burcu Caglar Gencosman (Uludag University)

14:40 - 15:40	Parallel Session - XXI	
Room: Pier Loti	Chair: Mohammad Al Mohsin	
ID: 51	Hybrid Multi-Criteria Decision Making Approach Based on Fuzzy AHP and Fuzzy TOPSIS Methods for the Stock Area Selection Problem	Ilker Kucukoglu (Uludag University) Betul Yagmahan (Uludag University) Ahmet Onayli (Uludag University) Ezgi Didem Cayhan (Uludag University) Merve Unal (Uludag University)
ID: 106	Vehicle Technology Selection with Integrated Fuzzy AHP-TOPSIS Method	Ibrahim Yazici (Istanbul Technical University) Omer Faruk Gurcan (Istanbul Technical University)
ID: 126	Comparison of Neural Network and Wrapper Methods for Decision Making: Acceptance of Fabrics in Quality Control Process	Duygu Yilmaz Eroglu (Uludag University) Burcu Caglar Gencosman (Uludag University)

15:40 - 16:10	Poster Session	
Room: Galata Fuaye		
ID: 74	Modeling and Simulation of Transport of Insulin Aerosol into the Lungs at the Level of Trachea	Djerafi-Kaabeche Khatima (National Technical University of Constantine) Nekaa Amine (National Technical University of Constantine) Saouli Ouacil (National Technical University of Constantine)
ID: 120	Simulations of Linear and Nonlinear Respiratory Mechanics on Optimization of the Human Respiratory Control	Shyan-Lung Lin (Feng Chia University - MingDao University) Chieh-Liang Wu (Taichung Veterans General Hospital)

15:40 - 16:10	Break - Galata Fuaye

16:10 - 17:10	Parallel Session - XXII	
Room: Ayasofya	Chair: Hatice Camgoz Akdag	
ID: 38	Supply Diagnostic Incentives in New Product Launch	Mohammad E. Nikoofal (Católica Lisbon School of Business & Economics) Mehmet Gumus(McGill University)
ID: 68	A Review of Reverse Logistics Studies and Assessing Future Trends for Turkey	Mustafa Kocabas (Turkish Air Force NCO College) Berna Ulutas (Eskisehir Osmangazi University)
ID: 115	Solving Container Sequencing Problem Using Hybrid Tabu Search Method	Osman Kulak (Pamukkale University) Yusuf Yilmaz (Pamukkale University) Aybuke Alper (Pamukkale University) Mustafa Egemen Taner (Pamukkale University)

16:10 - 17:10	Parallel Session - XXIII	
Room: Rumeli	Chair: Tarek Y. ElMekkawy	
ID: 99	An Effective Heuristic Policy for a Recoverable Manufacturing System with Substitutable Products	S. Sebnem Ahiska (Galatasaray University) Russell E. King (North Carolina State University) Fethullah Gocer (Galatasaray University)
ID: 112	A GA Approach for Minimizing Total Manpower Shortage in Synchronized Manufacturing Cells	Gursel A. Suer (Ohio University) Sara Akbar Ghanadian (Ohio University) Fatih Yarimoglu (Ohio University)
ID: 128	Hybrid Method for Large Scale Scheduling Problem	Duygu Yilmaz Eroglu (Uludag University)
18:00 - 20:00	Gala Dinner - Beylerbeyi	

GJCIE 2016

Global Joint Conference on Industrial Engineering and Its Application Areas

14 – 15 July 2016 – Istanbul, Turkey

“Building Successful University-Industry Alliances”

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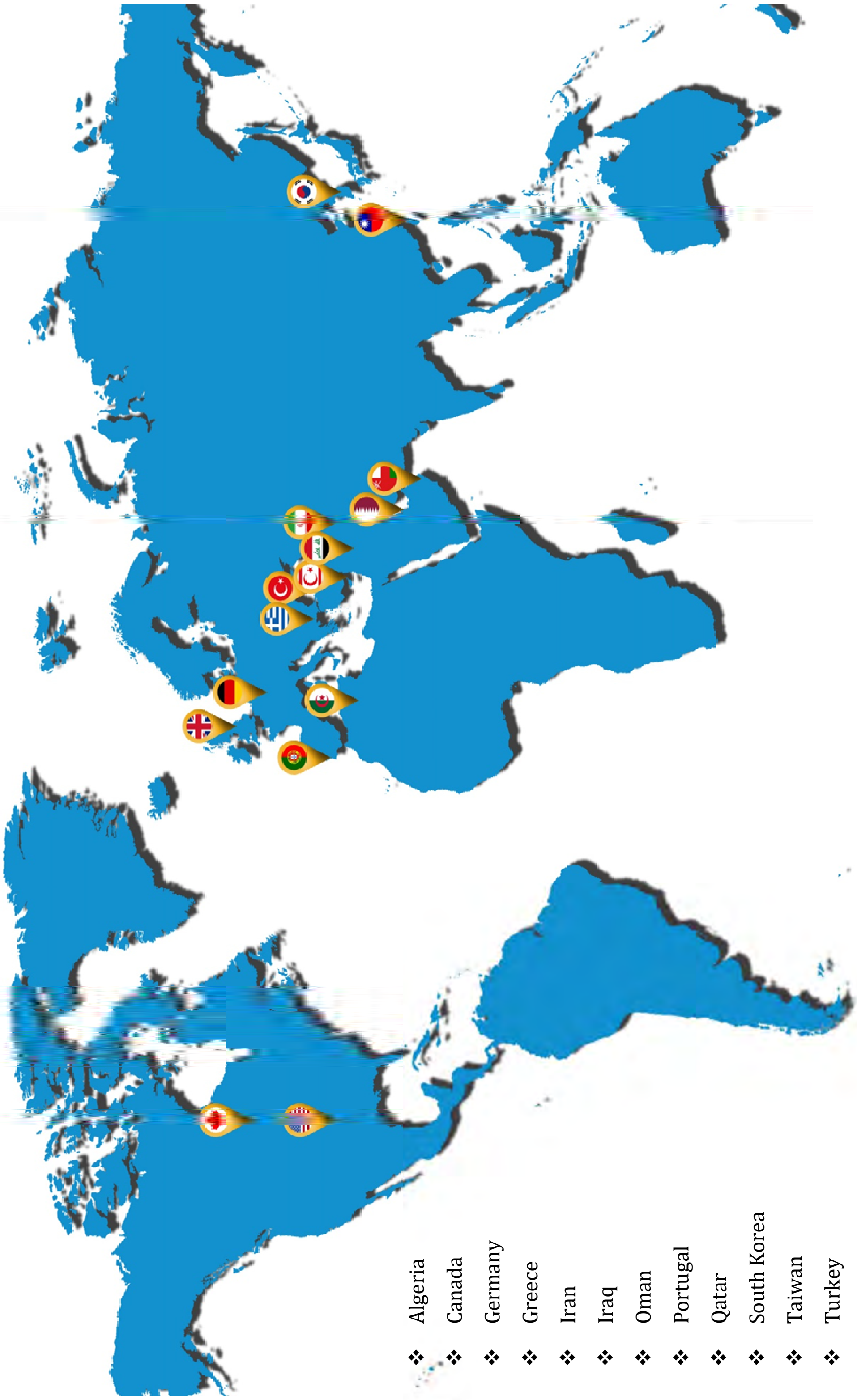

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GJCIE 2017

Global Joint Conference on Industrial Engineering and Its Application Areas

20 – 21 July 2017 – Austria Trend Hotel Savoyen
Vienna, Austria

Organized by
Istanbul Technical University

"INDUSTRIAL ENGINEERING IN THE INDUSTRY 4.0 ERA"

Industry 4.0 is a collective term for technologies and concepts of value chain organization which brings together Cyber-Physical Systems, the Internet of Things, the Industrial Internet of Things, and the Internet of Services. These systems allow intelligent products, processes, and services to communicate with each other and with people in real time over a global network. This challenges the way we educate engineers and the way we manage companies. The Global Joint Conference on Industrial Engineering and Its Application Areas (GJCIE) 2017 will shed light on the role of industrial engineering in this endeavor.

The GJCIE 2017 is composed of three co-located conferences: the 2nd Global Conference on Industrial Engineering (GCIE), the 4th Global Conference on Engineering and Technology Management (GCETM), and the 3rd Global Conference on Healthcare Systems Engineering and Management (GCHSEM). The GGJCIE 2017 will be an internationally renowned forum for researchers, practitioners, and educators to present and discuss the most recent innovations, trends, experiences, and challenges in the field of industrial engineering. It will bring together experts from academia and industry to exchange the latest research results and trends, and their practical applications in the aforementioned areas of industrial engineering. This will be accomplished through the following three modes of communication: keynote presentations, parallel sessions, and poster sessions.

Vienna, the capital of Austria, is one of Europe's most fascinating cities with a rich history and various cultural attractions and reasonable living costs. The city lies in the east of Austria and is close to the borders of the Czech Republic, Slovakia, and Hungary. Vienna is home to about 2 million people, and from 20 to 21 July 2017, will also be home to the GJCIE 2017.

GJCIE 2017

Global Joint Conference on Industrial Engineering and Its Application Areas

20 – 21 July 2017 – Austria Trend Hotel Savoyen
Vienna, Austria

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"INDUSTRIAL ENGINEERING IN THE INDUSTRY 4.0 ERA"

Important Dates

Full Paper Due for Review	March 3, 2017
Notification of Full Paper Acceptance (with any requested changes)	April 7, 2017
Final Full Paper Due (with changes)	May 5, 2017
Early Registration Deadline	May 5, 2017
Final Author Registration Deadline	May 26, 2017

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Determining the Optimum Number of Trucks in Pavement Process

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Abstract

Highway projects are often suffering from uncertainty along with a degree of complexity, which lead to many challenges in planning because of the stochastic nature of these projects. The stochastic nature is reflected in a form of a wide range of probabilities in the planning parameters, mainly the time required to implement tasks of highway construction. The aim of this paper is to introduce a simulation model to optimize fleet size, particularly the number of trucks required for pavement fleet. The optimization will be based on minimizing the cost of waiting time for the three main components of the pavement process (batching plant, trucks, and paver). Monte Carlo simulation tool is adopted for the proposed model where uncertainty is to be applied to show the stochastic nature of the model. The proposed model has been tested using an actual data from pavement project to find the optimum number of trucks, where the optimum number of trucks($40m^3$) was three.

Keywords

Pavement fleet, Highway Construction, cost optimization

1. Introduction

One of the most important components of infrastructure is highways, where pavement plays a core activity in the construction. The asphalt paving industry has reaped the advantages of ever-advancing technology to improve the productivity of labor and equipment. Gransberg (1996) presented a model for optimizing haul unit size and number based on a function of loading facility characteristics as modeled by a load growth curve. The model relies on the derivation of a cost index number to determine the optimum size and number of haul units for the given loading facility. The use of this model provides a mean to design the construction equipment fleet for a wide range of material moving projects. Another work was done by Moselhi and Alshibani (2007) to optimize construction time and cost. Marzouk and Moselhi, (2004) presented a framework for optimizing earthmoving operations using computer simulation and genetic algorithms. The optimization aimed to minimize time and cost of earthmoving operations. The proposed framework considered factors that influence earthmoving operations including equipment availability and project indirect cost. It supports time-cost tradeoff analysis and allows “what-if” scenarios with respect to fleet configurations, in the same field Alshibani and Moselhi (2012) presented a newly developed optimization simulation model for fleet selection for earthmoving operations for the purpose of selecting equipment fleet configurations for earthmoving operations. AbouRizk et al. (2011) presented a construction simulation case study based on a history of construction simulation theory to produce an automated project planning and control. Li et al (2009) used Virtual Prototyping computer simulation to optimize construction planning schedules by analyzing resource allocation and planning with integrated construction models, resource models, construction planning schedules and site-layout plans. This system allows a range of 'what-if' questions to be asked and their implications on the total project to be investigated. Choi and Minchin (2011) used measured daily production rates for highway pavement construction, verified factors that adversely affected performance, and quantified the loss of work hours caused by each factor. They found that productivity in highway pavement construction contains significant variability. In the process of developing optimization models, Jrade and Markiz (2012) developed an automated optimization model in order to assist contractors in this multifaceted task. Economical operation analysis is conducted for an equipment fleet while taking into consideration the owning and operating comprehensive costs involved in most of earthwork operations. They concluded that the proposed model provides optimum equipment fleet to perform earthwork operations based on their economical operation analysis by providing the user with a final optimized report that includes ownership and rental options. Jalili (2012) presented the framework of a microscopic discrete-event simulation system for modeling earthmoving operations and conducting productivity estimations on an operational level. They claimed that the proposed model is capable of evaluating alternative operating strategies and resource utilization at a very detailed level. Jalili et al (2013) presented a methodology that combines discrete-event simulation and optimization to solve the optimal fleet selection problem for earthmoving operations. Two optimization objectives were formulated and solved using the proposed framework and a genetic algorithm: minimization of total cost of ownership and maximization of productivity. They concluded that the proposed mechanism can effectively allocate an optimal equipment combination for earthmoving operations and hence serve as an efficient tool for construction management. Marinelliand Lambropoulos (2013) proposed a new algorithmic optimization method that incorporates the golden section search and the bisection algorithm to achieve an improved modeling of scraper earthmoving operations and contributes toward a more efficient cost management

It is clear from the above that many researchers have tried to solve the exiting problems of management of asphalt fleet with an ambition of reducing the cost and increasing productivity using different models. However, many of these models rely on outputs of other programs as an input for their models. Others use high-tech instruments for monitoring and assessing the production of equipment which may not be available to many companies. In addition, some of these models are geared towards local conditions. A simple and general model that can be used for different types of projects with minimum input is required.

The hauling of asphalt mix can be considered as milestone for pavement process where the utilization of batching plant's and paver's productivities requires efficient hauling operation. Failure to meet such productivities would lead to time and cost overrun. The whole process of paving suffers from uncertainty but it is more pronounced in the hauling operation due to involvement of different variables including hauling units' capacities, road condition, distance of haul, traffic condition, operators, road closures, human factors etc.

Most of the existing models for planning and appraising of asphalt operations suffer limitations in terms of simplicity and generality of use as explained above. The aim of this paper is to introduce a simulation model to optimize fleet size, particularly the number of trucks required for pavement fleet.

2. Methodology

In order to minimize the cost of pavement fleet, the waiting times of all components were optimized as follows:

1. Estimated hourly production rates of batching plant and paver were studied. This is based on previous records of similar works. The lower hourly production rate of the batching plant and the paver is called the equipment production rate.
2. The time of one complete cycle of a truck was measured based on capacity of the truck, hauling distance, road and traffic conditions to determine the production rate of one truck.
3. The production rate of the paver is divided by the production rate of a tuck to estimate the minimum number of trucks n required.
4. Use the diagram shown in Figure 1 with the minimum number of trucks n and carry out simulation until an optimal number of trucks is reached. If n was found to be with a digit use the lower complete numeral.

The main concept of the suggested model is to start with the minimum number of trucks meanwhile this number to be increased stepwised, for every increase the whole process will be simulated to calculate the times required for the four components (loading, hauling, unloading, and return). Waiting times is to be calculated based on the simulated times, eventually the cost of waiting time for the fleet will be calculated. The criteria of stopping the simulation runs where the cost of waiting time starts to increase, which means increasing in the wastage of resources due to the high waiting time for the entire system of pavement.

The sample fleet comprised the following components:

- Paver, with average productivity of 200 m^3/hr
- Batching plant, with an average productivity of 130m^3/hr
- Trucks, 40 ton capacity for each.

The developed simulation model was processed through the use of excel spread sheet designed by the authors to comply with the above approach and calculate waiting time for different paving operations. The first run started after the basic data was collected for each activity which was used in the simulation process to generate more data. Each iteration constitutes generation of times of batching plant, trucks, and paver.

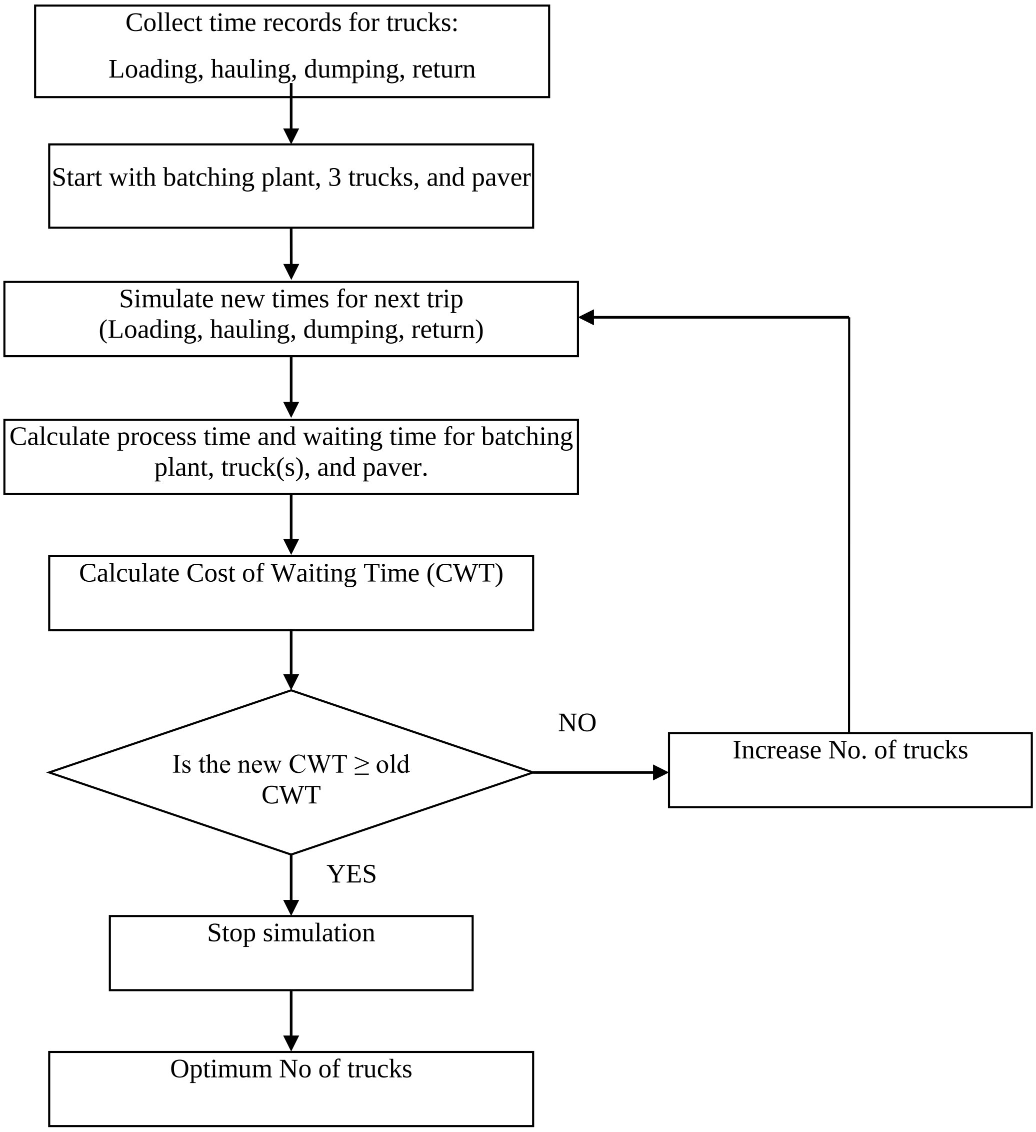

Figure 1: Conceptual scope

3. Results and discussion

A sample of result for three-truck(n) model is presented in Table 1 to show the behavior of waiting time subjected to simulation of loading, hauling, unloading, and return to the batching plant.

Figure 2 shows the calculated elapsed time for different activities in addition of the waiting time based on the logical relationship between the different activities that determine the occurrence of waiting time using three hauling units (n). The results shown in this figure are extracted from the first iteration. This scenario applies the rules put in the above methodology, which results in calculating the waiting time in different iterations at different component (batching plant, hauling units, and paver).

Table 1: Sample of times in seconds used in the first run (iteration)

Batching plant		Truck 1(T1)		Truck 2 (T2)		Truck 3 (T3)		Paver	
Waiting	0	Waiting	0	Waiting	18	Waiting	43	Waiting	88
Loading T1*	18	Loading*	18	Loading	25	Loading	27	Unloading T1	13
Loading T2	25	Hauling	70	Hauling*	55	Hauling	59	Unloading	16
Loading T3	27	Unloading	13	Waiting	2	Unloading*	13	Waiting	12
waiting	81	Return	50	Unloading	16	Return*	50	Unloading	13
Loading T1	23	Loading	23	Return	43	Waiting	2	Waiting	95
Loading T2	20	Hauling	63	Waiting	14	Loading	22	Unloading T1	12
Loading T3	22	Unloading	12	Loading	22	Hauling	53	Unloading T2	11
Waiting	73	Return	40	Hauling	55	Unloading	15	Waiting	9
				Unloading	11			Unloading T3	15

*Time values are actual records; other values are simulated.

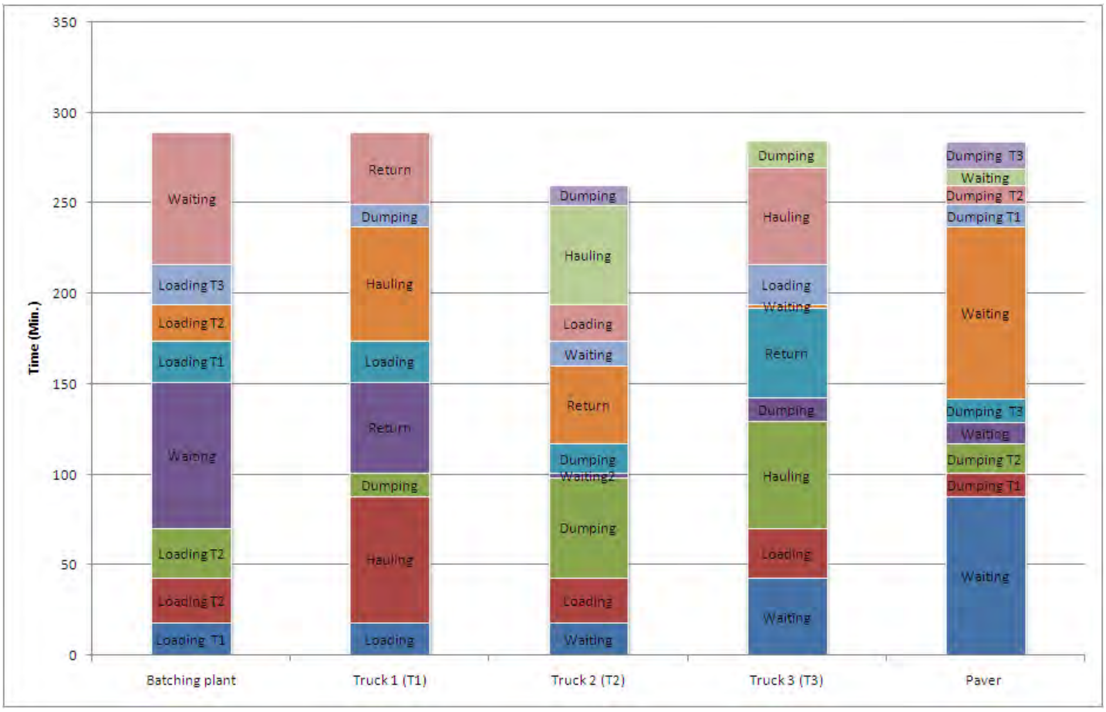

Figure2: Sample of results

The second and third iterations follow the first one and processed by increasing the number of trucks to 5 and 6 respectively. The waiting time is evaluated at each iteration for the purpose of calculating the cost of waiting time (CWT). Successive iterations are carried out while the curve of the cost of waiting time is descending; the iterations are stopped once the curve starts ascending. The waiting time reached by the end of this simulation is considered as the optimal time, which leads to minimum cost of waiting time. This process is repeated in case of any variable has changed i.e. size or number of hauling units, hauling distance, traffic, etc. This allows facilitating the changes as they appear. A huge list of elapsed times for each stage of work (loading, hauling, unloading, and return) is generated through the process of simulation. Waiting times for these stages are used for optimizing waiting time for the purpose of minimizing cost of waiting time of the fleet.

The number of cycles (round trips) in each iteration is allowed to reach 100. It was found that the production of the fleet (batching plant, 1 paver, and 3 trucks) in the first iteration was 7644 ton of asphalt mix paved. In order to assess the ceiling for the different iterations, the quantity found in the first iteration was fixed for the successive iterations using different number of trucks (5 and 6 in this case). Table 2 shows the results of waiting time in three iterations while Table 3 shows the cost of waiting time for the three iterations.

Table 2: Waiting time for the three iterations

Iteration No.	Asphalt Paved Ton	No of trucks	Average waiting time (min)								
			Batching plant	Trucks							Paver
				T1	T2	T3	T4	T5	T6	Total	
1	7644	3	241.37	10.78	12.08	2.27				25.13	268.14
2	7644	5	45.69	20.99	20.74	17.27	12.47	1.16		72.63	234.17
3	7644	6	2.17	53.06	57.39	44.47	41.75	32.2	24.1	252.97	263.87

Table 3: Cost of waiting time for pavement fleet

Iteration		1	2	3
No. of trucks		3	5	6
Av. waiting time (min.)	Batching plant	241.37	45.69	2.17
	Trucks	25.13	72.63	252.97
	paver	268.14	234.17	263.87
Hourly cost(ID)	Batching plant	218570.00		
	Trucks	62763.16		
1$=1200(ID	paver	114668.80		
Waiting cost (ID)	Batching plant	879270.7	166441.1	7904.948
	Trucks	26287.57	75975.58	264622.6
	paver	512454.9	447533.2	504294.3

The results shown in Tables 2 and 3 reveals that the first iteration of simulation accompanied with the largest waiting time for both paver and batching plant, meanwhile the waiting time for trucks is very low as compared with that for paver and batching plant. In term of money, the cost of waiting time of the batching plant is the highest in this iteration followed by the cost of waiting time of the paver, the cost of waiting time of trucks is the lowest in this iteration. The differentiation in ranking of the three fleet components has resulted from the difference in hourly cost of each, where the batching plant has the highest hourly cost, followed by the paver, then the trucks.

It is obvious, in the first iteration, that the waiting time of both paver and batching plant are significantly high. One of the ways to reduce such high waiting time is adding one or more trucks. In the second iteration, Truck 4(T4) and Truck 5(T5) have been added to the fleet resulting in a reduction in the waiting times of batching plant and paver.

The drop of waiting time of the batching plant in the second iteration now has become more pronounced, resulting in a form of cost decrease (around 5 times). On the other hand, the total waiting time of trucks has tripled (approximately) due to more waiting for the trucks to the paver and batching plant. The reduction in the waiting time of the paver was marginal. The results of this iteration led to a reduction in total cost of waiting time to approximately halve of first iteration.

Truck 6 was added in the third iteration showing a continuous decrease of waiting time of the batching plant, it can be said that the batching plant now is almost fully utilized. The rate of waiting time of the trucks continued to increase. The waiting time of the paver increased while the waiting for the batching plant slightly decreased. The yield of the third iteration represented in term of total cost starts to increase indicating loss in the optimality incurred in the second iteration.

The waiting time of all components randomly changed (negatively or positively) in each iteration which certainly affected the cost of waiting time, therefore the third iteration was needed to prove the optimality of the second iteration due to the pattern of variation in the waiting time.

In the second iteration, it was expected that the drop in the waiting time of the paver to be higher than that for the batching plant. However, the results showed the opposite. The main reason behind unexpected situation is the effect of simulation. The simulated values of time vary randomly between minimum and maximum. Therefore, this effect was significantly positive in the drop of waiting time in the paver and was negative in the batching plant. The random variance is reflected in this model in a sharp drop of waiting time of the batching plant and a smooth drop of waiting time in paver.

The maximum waiting time in the entire simulation has been found n the first iteration for the paver (268.14 min.) because of shortage of asphalt supply with respect to the productivity of the paver. For the same reason the batching plant has achieved its maximum value of waiting time. The high value of waiting time of the paver reflects the need for more asphalt mix either by increasing the number of trucks or by using higher capacity trucks. In research, the capacity of the truck used was maximum available (40 tons), therefore, there was a need to increase the number of trucks.

In general, the waiting time of the trucks shows exponential continuous increase for the three iterations as shown in Table 2.

The sequence of the truck queue had a pronounced impact on the waiting time of a truck. For that, no waiting time has shown for truck No. 1 in the first iteration, while the total waiting time incurred from the waiting of trucks 2 and 3.

No trend in the pattern of change in the waiting times for all components of paving fleet, because of the effect of simulation which assumes non-deterministic behavior of times calculated for scheduling. The effect of simulation was vital on the time elapsed for each stage of the work of pavement, and consequently on the waiting time and finally on the cost of waiting time.

It is clear that for the sample used here, the optimal fleet was as follows:

- One paver, with average productivity of 200m^3/hr
- One batching plant, with an average productivity of 130m^3/hr
- 5 Trucks 40 tons' capacity for each.

4. Conclusions

Based on the results of this research, the following points are considered as concluding remarks:

1. A general and simple model for planning and appraising the paving operation is proposed. The waiting times of every fleet component (Batching plant, Paver, and Hauling Units) were planned and continuously evaluated to come up with optimal cost efficiency.
2. A sample of using one batching plant with productivity of 130m^3/hr, one paver of productivity of 200m^3/hr were used. The transporting trucks were varied from three to five. Each truck capacity was 40 ton.
3. It was found that:
   - The waiting time of the batching plant plays a major role in the cost of waiting time of the fleet due to high hourly cost of waiting time of the batching plant.
   - The waiting time of the paver went through minimal variation resulting in same cost of waiting time.
   - The optimal size of pavement fleet for the sample used was: Paver: with average productivity of 200m^3/hr, batching plant: average productivity 130m^3/hr, and Trucks – 5 Nos. each 40 ton capacity.
   - Increasing the number of trucks offset the high capacity of batching plant to reduce the waiting time of batching plant.
   - Adding one more paver would reverse the whole system but this case is rarely used due to the technical difficulties.

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Biography

Mohammed Al Mohsin is an Assistant Professor of Construction Management at the University of Buraimi, bachelor from the university of Technology- Baghdad 1992. Master holder in the field of Construction Management from the University of Technology – Baghdad 1996, his PhD from the same department at 2006. 11years of experiencing construction industry followed by another 11 years in the academic filed teaching construction management courses along with research in the same area as well as interests of cost management of construction, optimization in construction industry.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Effect of Supplier’s Assessment on Waste Prevention

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Abstract

Since the industrial revolution, the natural resources have been exploited vigorously throughout the world. Therefore, governments and customers force organizations to produce more economic, sustainable and green items. Beyond the financial, social and legal perspective, producers are challenged by environmental constraints while managing their supply chain. A questionnaire was specifically designed in this research and submitted to company managers and to both businesses related and unrelated suppliers. Therefore, this study considers the effect of selection, incentive and development of suppliers. Behavioral, structural and economic barriers, which may lead to some restrictions, are also investigated in this research. Moreover, the difference of opinion between related suppliers and unrelated suppliers is studied by using hypothesis testing. This research revealed that 95% of managers find supplier development as the most effective motivation towards waste prevention, and 50% of them think economic barrier limits the supplier practices. This can be concluded that supplier development has the most positive effect on waste prevention and economic barrier has considered as the strongest barrier. Furthermore, there were difference of opinion between related and unrelated suppliers with regards to incentive and selection practices ($p<0.05$).

Keywords

Supply chain, Supply chain management Practice, Waste management, Environment

1. Introduction

The global situation is worsening in terms of various environmental, economic and socio-political etc., arenas. The ever-increasing environmental pollution due to the industrial wastes the raw materials becoming more and more expensive, greedy consumption and the resulting emptying of natural resources, and further, the worldwide high rate population rise, all are collectively developing critical situation across the globe. As a result, the competition for natural resources is fierce (Štreimikienė, 2012) greatly impacting the business worldwide, creating an enormous impact on global businesses. The European community (EC) in its strategy developed for the year 2020 in view is emphasizing the waste-to- resource conversion and has set the goal of re-structuring the current legal system as well as promoting the waste mitigating initiatives.

Furthermore, the knowledge and awareness among the consumers is escalating. Such an approach requires continuity and for it to be ensured, the financial goals are to include social participation and enhancing environmental performance (Seitanidi & Crane, 2013). Enterprises should abandon entirely the non-value added wastes and focus to promote their processes and resources to value-added scale, implement efficiency of use, decreasing re-procurement and thereby reducing the disposal operation and expenses. Accordingly, the smaller the consumable input volume, the smaller size/volume of the output waste, if achieving more value objective is followed throughout all processes.

This research is yielded base on practice and persuade suppliers to more sustainable performance by selection and evaluation of them. Furthermore, achieving sustainable suppliers can be ad equated by supplier incentive like awarding certain status. The present practice-oriented thesis constitutes such changes as its commencement point and considers the Iran Khodro Industrial Die (IKID) performance as the defined ‘practitioner’.

IKID, which would be affected by the forthcoming developments in legal domains concerning waste policies, seeks implementing dynamic methods for managing its wastes aiming at prior complying with the future changes in bylaws and regulations. Hence, the main aim of this study is generalizing the knowledge of the practitioner (Hak, 2008) and developing a dynamic model capable of offering an appropriate solution for management of the wastes in all the company premises including the main office of IKID. In addition, answering the questions are explained in the conceptual model is the other aim of this research.

2. Literature Review

Due to the increasing waste of industrial sectors and at the same time rising cost of raw materials, growing population and the most important reducing natural resources, firms should find the effective methods in order to optimize the usage of sources and reduce waste.

Particularly, from the supply chain management point of view, previous researches and studies show the fact that suppliers play an important role in this issue. So, more attention must be taken by firms in to consideration about supplier selection strategies and supplier's development.

Supply chain is generally defined as a series of stakeholders consist of suppliers, customers, logistic providers that contribute in a synergic way to deliver value packages of products to the end customer (Simchi-Levi et al., 2007). Although suppliers are significant part of each industry organization, one of the challenges firms are faced by green practicing is the inadequacy of green products from suppliers (Kasim & Ismail, 2012). The aim of firms in supply chain is complying some practices tend to reduce waste disposal, reverse energy, deduction pollution, recycle and take steps to responsible use of natural sources (Scharge, 2004). One of solution which is considered in one of Japanese manufacturer for reducing waste is that assemblers trend with suppliers that generate less waste to incline toward better environmental performance (Hayami et al., 2015).

Supply managers must approach to reduce waste and emissions that are not under their direct control by providing information and incentives for customers and suppliers, (Plambeck, 2012). One of the most appropriate solutions can be recommended by supply chain managers in order to reduce waste in manufacturing corporations is imposing penalty on greenhouse gas emissions (Chen et al., 2013). Furthermore, intensive competition among firms is yield by supplier selection, can be another solution in order to decrease waste. Supplier selection method can be applied for all suppliers from row materials to end of life service providers (Azadi et al., 2015).

Supplier selection refers to the process of gathering and processing information in order to assess and approve the performance of suppliers or potential supplier (Klassen & Vachon, 2003). In supplier selection procedure, various factors such as quality, price, flexibility and supplier authority are considered by firms. Some of these factors are visible and some of them are invisible (Bai & Sarkis, 2010); moreover, within supplier selection performance, suppliers are assigned grades in order to achieve an effective method for selecting appropriate suppliers. For evaluating suppliers, the Analytic Hierarchy Process (AHP) method is used by Yahya and Kingsman (Yahya & Kingsman, 1999).

According to Simpson and Power (2005) Krause et al. (2000), supply incentives are meant to "motivate suppliers to improve by signaling that improve performance is rewarded with increased business and preferred status for future business". Innovative competitive advantages to member's causes to improve performance of the supply chain (Wu et al., 2012). Furthermore, supplier development is one of the significant factors to achieve development in manufacturer companies (Krause et al., 2000). Commonly, achieving improvement can be more straightforward when two or more companies work together than working individually (Simatupang & Sridharan, 2002).

Waste prevention is either about waste, or practical, effective and new ways for handling with resources. Eco-innovations are needed to optimize the whole chain in order to increase resource efficiency (Wilts et al., 2013).The main goal of waste prevention is to minimize the adverse effect of waste generation (Dehoust et al., 2011). The most important aspect of waste prevention states preventing or reducing the adverse impacts of the generation and management of waste in order to protect the environment and human health and by reducing overall impacts of resource use and improving the efficiency of such use (Wilts et al., 2013).

3. Methodology

This research has been prepared based on the needs of the company in the field of environmental and waste reduction. In addition the aim of this research is to answer questions characterized in the theoretical model. Overall, Environmental Supply Management Practice (ESMP) is focused on one ecological problem; waste counteractive action.

Due to the difference between industries, it is more justifiable to concentrate on one specific industry. In this research one of the automotive manufacturing of Iran is the main focus of the study. This industry is more suitable to the topic as it is characterized by close collaboration and high complexity of supply chain. Significant of hypothesis on ESMP and related practices is done inside of a Manufacturing Automobile Industry (MAI), considering both central firm and their related and unrelated suppliers. Related supplier means suppliers which currently have business with the MAI. Unrelated suppliers however considered as potential suppliers which may have business in the future.

This study is practice oriented and a hypothesis-testing methodology is employed based on the method proposed by (Dul & Hak, 2007). The method is already tested in shipbuilding industry (Berdien, 2014). Manufacturing of industrial dies is assessed from principal company and supplier's perspective. In fact, feasibility of environmental supply chain management practices is examined in specific situation by several outlooks. In order to reduce the bias of interviewer, different managers were interviewed according to the type of their activities in company.

Questionnaire was sent to managers of MAI including 2 purchase managers, 4 quality managers and 2 production managers. In addition, the questionnaire was answered by quality managers of 12 external supplier companies. External companies were divided in 6 related suppliers and 6 unrelated. In order to avert confidentiality affairs interviewees are called as Manager1 (M1), M2 and etc. It should be mentioned that M1 to M8 are the MAI managers but M9 to M16 are each owned by one different company. Furthermore, all cases were asked whether they are ISO14001 certificated or not. This certification determines the commitment of companies toward environmental policy.

Two types of questions; binary (0 or 1) and Likert type scale (range 1-none to 5-very high) were considered. Factual questions were patterned in Binary form and personal approaches were patterned in Likert Type form. In addition, relation between variables in the conceptual model is defined by selected questions (Figure 1). Two sections are included in the questionnaire as independent variables and barriers. The first section contains for practices of supplier selection, evaluation, incentive and development. The second section consists of 3 types of barriers; behavioral, structural and economic. These barriers may create problems which can restrict environmental practices. All of the definitions related to ESMPs and barriers are gathered in Table 1. The questionnaire aims to identify which type of ESMP's practices can motivate suppliers to endorse waste prevention policies.

Interview is provided by e-mail including a brief introduction on the research and questionnaire. In addition external suppliers' interview was approached by both email and phone. The full questionnaire is provided in Appendix (2). It should be noted that questions 8, 9, 12, 13, 16 and 18 were answered only by suppliers.

The conceptual model was arranged based on the need of IKID and statement of (Meredith, 1993). Figure 1 illustrates this conceptual model of this study.

A positive outlook is expected by supply selection practice. According to (Carter, 1998) ESMP is illustrated to have a positive influence in terms of corporation with suppliers in projects that are related to environment. Furthermore, waste reduction is gained by supplier evaluation (Simpson & Power, 2005). Since, supplier evaluation plays a controlling role; positive influence on waste management is expected (Lamming & Hampson, 1996; Simpson & Power, 2005). Alongside the supply determination and assessment, suppliers are persuaded by motivations. In order to motivate suppliers, Supply incentives are allocated some rewards like deliberation of prospective business, large amount of the present item and encouraging supplier condition by prize (Krause & Scannell, 2002). Supplier development also is considered as an incentive for suppliers. Supplier development is scoped to include collaboration, progress of the supplier and training (Hoejmose & Adrien-Kirby, 2012).

Table 1: Definition of independent variables and barriers

Construct	Definition
Supplier Selection	The search for, assessment of and decision to contract potential suppliers based upon requirements that incorporate environmental concerns and thus manage supply chain risks and supply-base continuity.
Supplier Evaluation	The processes of assessing a supplier's performance on environmental criteria in order to compare it across the supply base, reduce risks and inefficiencies, and investigate points of improvement.
Supplier Incentives	Rewards to proper environmental performance of suppliers in the form of increased (future) business or preferred status.
Supplier Development	Strategic efforts focused on relationship-building with suppliers such as collaboration on intra- and inter-organization processes, supplier involvement and education with the aim of long-term supply chain improvement.
Behavioral Barriers	Managerial and personnel attitudes and awareness with respect to ESM that may lead to mitigation of efforts or lack of involvement imposing a barrier to implementation.
Structural Barriers	The lack of resources, procedures, policies or strategies with respect to ESM that impose a barrier to implementation.
Economic Barriers	The (perceived) additional costs or lower profits with respect to ESM that impose a barrier to implementation.
Best Practice	An ESM practice in use that is deemed better than all other practices used elsewhere.
Waste prevention policies	Practices that are part of a sustainable and integrated strategy that underscores continuous improvement and aims to avoid waste and the generation thereof by employing a resource-efficient attitude to products and processes within the chain.

Conversely, environmental supply chain practices can be confronted by barriers in this case, suppliers outlook has a critical part (Hamner, 2006). Low level of recognition, redesign and observation in natural exercises might be lead to low adaption in firms. Moreover, the perspective that the high expenses connected with ESMP can prompt mistaken adaption of this practices by fundamental organization and suppliers (Barari et al., 2012). Accordingly, the core concepts of this model are summarized in Table 2.

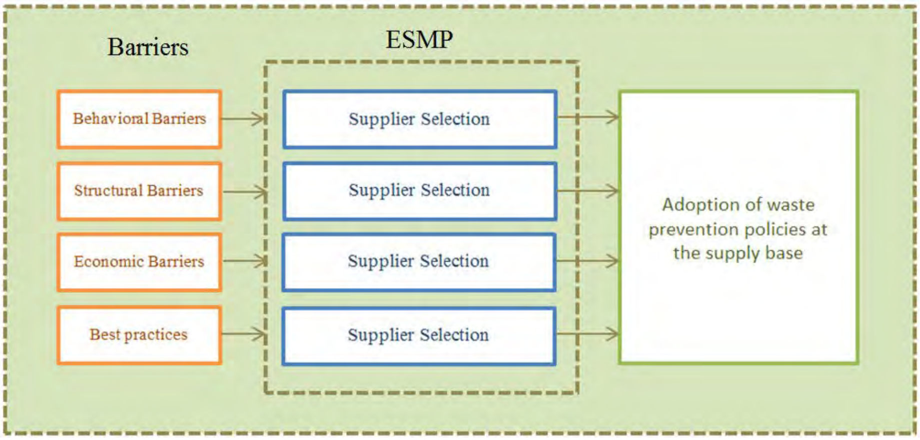


Figure 1: The conceptual model

In order to test H1 to H7, the method of Berdien (2014) is used. This method is based on Dul and Hak (2007) study and guided by the accompanying following principles. Overall scores are calculated by formula (1) and (2). These two formulas, determine whether the claims are confirmed or not. If formula (1) results a greater than or equal 75%, the claim related to that ESMP is accepted. In addition, if outcome of formula (2) is greater than or equal 37.5% the

Table 2: Hypotheses of conceptual model

Claim	Definition
H1	Determination of supply *selection* on natural criteria would have a *positive* effect on adoption of waste prevention policies at the supply base
H2	Determination of supply *evaluation* on natural criteria would have a *positive* effect on adoption of waste prevention policies at the supply base
H3	Determination of supply *incentive* on natural criteria would have a *positive* effect on adoption of waste prevention policies at the supply base
H4	Determination of supply *development* on natural criteria would have a *positive* effect on adoption of waste prevention policies at the supply base
H5	*Behavioral* (type 1) barriers are liable to *negatively* affect the adoption of waste prevention policies at the supply base
H6	*Structural* (type 2) barriers are liable to *negatively* affect the adoption of waste prevention policies at the supply base
H7	*Economic* (type 3) barriers are liable to *negatively* affect the adoption of waste prevention policies at the supply base

claim related to that barrier is accepted (Berdien, 2014). The rest of the calculations related to this method are explained in the appendix (1).

Independent variables (selection, evaluation, incentives and development) are assumed to be a positive approach for ESMP; therefor, The overall score related to these variables are determined as follows:

$$\text{Overall score of independent variables} = \frac{\text{Cases which are ranked greater than or equal to 3}}{\text{all of the cases}} \quad (1)$$

On the other hand, as barriers are assumed to have a negative impact on waste adoption policies, for each barrier, the overall score is determined by formula (2).

$$\text{Overall score for barriers} = \frac{\text{Cases which are ranked less than or equal to 3}}{\text{all of the cases}} \quad (2)$$

Supplementary, finding the most effective practice among different environmental supply chain practices and discover that how the practice are affected by barriers, are main aims of this research. According to Dul and Hak (2007) best practice is “a practice in use that is deemed better than all other practices used elsewhere”.

In order to determine the difference of opinion between related and unrelated suppliers, this study tests the significant differences of opinion in ESMPs. One-way ANOVA test is applied for hypotheses (α=0.05). According to Central Limit Theorem, Likert-scale questionnaire can be put in normal distribution category, as long as the averages are used as the dependent variable. Eventually Table 3 demonstrates the hypotheses.

Calculations related to H8-H11 are done by SPSS software.

4. Results and Analysis

All of the participants have environmental policies in their companies and also all the companies in this research has approved that they are ISO14001 certified. Table 4 demonstrates the results of the managers. These numbers is calculated from the average of answers related to each ESMP or barrier. According to method of Berdien (2014) the rest of the analysis are gathered in the table.

Table3: Hypotheses for investigating of difference of oponion

Hypothesis	Definition
H8	There is a significant difference of opinion between related and unrelated suppliers in supplier *selection* practice.
H9	There is a significant difference of opinion between related and unrelated suppliers in supplier *evaluation* practice.
H10	There is a significant difference of opinion between related and unrelated suppliers in supplier *incentive* practice.
H11	There is a significant difference of opinion between related and unrelated suppliers in supplier *development* practice.

In table 4, (X) represents the highest average of each manager among all the practices. If a manager has the highest average in to two or three places, the (X) would be divided by the number of replications. In addition (Y) represents the lowest score that each manager gave to each barrier. The same as (X), (Y) would be divided by the number of replication if needed. Moreover, dash sign in the table means that the manager did not answer the question or part;

Table 4: Results demonstrated by Berdien (2014) method

	Managers	ESMP				Barriers		
		Selection	Evaluation	Incentives	Development	behavioral	structural	economic
Internal respondents	M1	3.6	3.0	4.0 (1/2X)	4.0 *(1/2X)*	4.5	-	-
	M2	4.0 *(1/3X)*	3.5	4.0 *(1/3X)*	4.0 *(1/3X)*	3.7	-	-
	M3	4.0	4.0	5.0 *(1/2X)*	5.0 *(1/2X)*	4.5	-	-
	M4	4.6 (X)	4.5	4.0	4.0	1.5	-	-
	M5	3.0	2.5	4.0 *(X)*	2.0	3.0	-	-
	M6	3.0	4.0 (1/2X)	4.0 *(1/2X)*	3.0	3.5	-	-
	M7	3.0	2.5	4.0 *(X)*	2.0	3.0	-	-
	M8	4.3 (X)	4.0	4.0	4.0	5.0	-	-
	(%) | >=3 (ESMP) | =<3 (Barriers)	100	75	100	75	37.5	-	-
	# of manager's 1st score	2.3 (29%)	0.5(6%)	3.8(47%)	1.3 (16%)	-	-	-
External Respondents	M9	3.6	4.5 *(X)*	4.3	3.5	3.7	3.6 *(Y)*	4.0
	M10	2.6	3.5	4.0 *(1/2X)*	4.0 *(1/2X)*	3.5	3.0 *(1/2Y)*	3.0 *(1/2Y)*
	M11	2.6	4.3 *(1/2X)*	4.3 *(1/2X)*	4.0	3.7	3.0 *(1/2Y)*	3.0 *(1/2Y)*
	M12	3.6	4.0	4.3 *(X)*	3.5	4.5	4.0	3.0 *(Y)*
	M13	2.4	4.3	4.0	4.5 *(X)*	-	-	-
	M14	3.4	3.5	4.3	4.5 *(X)*	-	-	-
	M15	4.8 *(1/2X)*	4.8 *(1/2X)*	3.7	3.5	3.2 *(Y)*	3.6	4.6
	M16	4.0 *(X)*	3.3	3.3	3.5	3.6	3.3 *(Y)*	3.6
	M17	3.6	3.5	3.7 *(X)*	3.5	3.5	3.0	1.6 *(Y)*
	M18	4.6 *(X)*	2.5	2.0	4.5	4.5	4.3	3.3 *(Y)*
	M19	4.5 *(X)*	3.5	2.7	3.5	-	-	-
	M20	4.0	2.8	1.7	4.5 *(X)*	-	-	-
	(%) | >=3 (ESMP) | =<3 (Barriers)	75	83	75	100	0	37.5	50
	# of manager's 1st score	3.5 (29%)	2 (17%)	3 (25%)	3.5 (29%)	1 (12%)	3 (37%)	4 (50%)
Overall Score	(%) | >=3 (ESMP) | =<3 (Barriers)	85	80	85	90	18.75	37.5	50
	# of manager's 1st score	5.8 (29%)	2.5 (12%)	6.8 (39%)	4.8 (24%)	1 (12%)	1 (37%)	1 (50%)

therefore, it is omitted in the table.

Number (#) of manager's first score is the summation of (X)s in that practice. And also the percentage of managers who answered and ranked the highest score to the practice is shown in parenthesis.

Accomplishing answer of the primary examination question taking into account the connection between dependent and independent variables is the point of interpretation of discoveries which are accomplished under practice in IKID. Besides, the hypotheses were prepared with a specific end goal to discovering the connection among theoretical model's contraction taking into account the new hypothesis (Carter & Rogers, 2008).

The analysis is led by taking after principles. To start with, natural store network practice are considered as a positive usage when similarly or more than 75% of managers rank more than midpoint of scale (>=3). It implies that no less than 15 managers must esteem to ESMP for achieving that planned practice have assumed positive part. Picking this rate is emerging from confirmation bias that some of managers may seem more positive in view of their business connection they have with IKID.

Second, execution of barriers is considered as a negative part inside ESMP with respect to waste counteractive action suspicion when no less than 37.5% of managers assigned not as much as midpoint scale (=< 3). Also some of cases in order to seem positive may be underestimate barriers. Hence, this percentage is selected. Finally, using formula (1) for ESMPs and formula (2) for barriers in below of the table4, the overall score of ESMP and barriers are calculated. According to achieved results, overall score of selection, evaluation, incentive and development is higher than the threshold of 75%; therefor, H1 to H4 claim are proved to be correct. In the barrier section of the table, behavioral barrier has the overall score of 12.5% which is less than 35% the claim cannot be accepted by these evidences. H6 and H7 can be accepted by the results because the overall scores are higher than 35% in both scenarios.

Related to H8-H11, Table 5 clarifies a full report of descriptive statistic of the questionnaire outcome. Table 6 tests the homogeneity of the variables by Levene statistic method. It can be concluded that incentive practice does not have the equality of variances assumption (p-value = 0.002); therefore, it is better to use Brown-Forsythe test which is more appropriated. With regards to outcome of table 6, table 7 would test the difference of opinion of related and unrelated suppliers. According to this table, selection and incentive practices have significantly different results between related and unrelated suppliers (p-value<0.05).

Table 5: Descriptive of independent variables

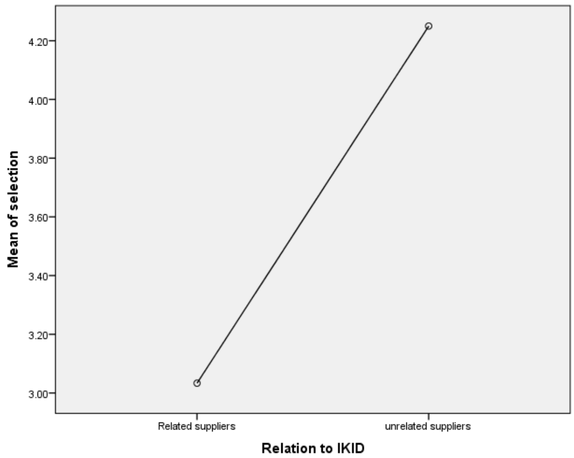
Practice	Levels	n	Mean	SD	95% Confidence Interval		Minimum	Maximum
					Lower bound	Upper bound		
Selection	Related	6	3.03	0.56	2.45	3.62	2.40	3.60
	Unrelated	6	4.25	0.45	3.77	4.73	3.60	4.80
	Total	12	3.64	0.80	3.13	4.15	2.40	4.80
Evaluation	Related	6	4.00	0.42	3.56	4.44	3.50	4.50
	Unrelated	6	3.37	0.79	2.55	4.20	2.50	4.75
	Total	12	3.69	0.68	3.25	4.12	2.50	4.75
Incentive	Related	6	4.22	0.17	4.04	4.40	4.00	4.33
	Unrelated	6	2.83	0.86	1.93	3.74	1.67	3.67
	Total	12	3.53	0.94	2.93	4.12	1.67	4.33
Development	Related	6	4.00	0.45	3.53	4.47	3.50	4.50
	Unrelated	6	3.83	0.52	3.29	4.38	3.50	4.50
	Total	12	3.92	0.47	3.62	4.21	3.50	4.50

Table 6: Test of homogeneity of variables

	Levene statistic	df1	df2	P-value
selection	1.976	1	10	0.190
incentive	16.233	1	10	0.002
evaluation	0.845	1	10	0.380
development	0.769	1	10	0.401

Table 7: Test results of four practices

		Sum of squares	Df	Mean square	F-statistic	P-value
Selection	Treatment	4.441	1	4.441	17.157	0.002
	Error	2.588	10	0.259		
	Total	7.029	11			
Evaluation	Treatment	1.172	1	1.172	2.953	0.116
	Error	3.969	10	0.397		
	Total	5.141	11			
Development	Treatment	0.083	1	0.083	0.357	0.563
	Error	2.333	10	0.233		
	Total	2.417	11			
Incentive		Statistic	Df 1	Df 2		P-value
	Brown-Forsythe	14.952	1	5.397		0.010



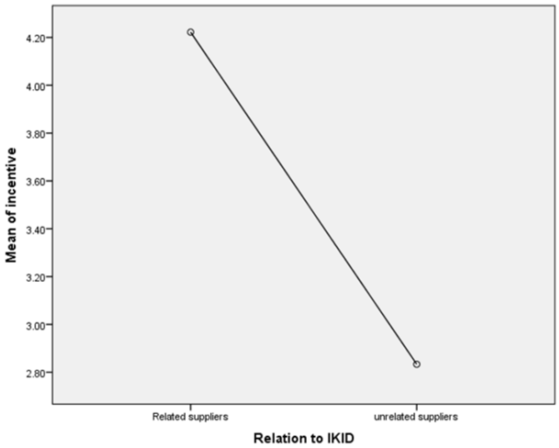


Figure 2: Mean plot for selection and incentive practices

Figure 2 is demonstrated in order to show the difference of opinion in these two practices. Since the practices contain two levels, multiple comparisons in the treatments of selection and incentives cannot be applied; therefore, mean plot of the two practices can gives the perspective of these differences. According to left mean plot, external suppliers who are related to IKID, answered supplier selection section of the questionnaire with lower effectiveness approach. On the other hand, right mean plot clarifies a higher credit for incentive practice among suppliers who are not related to the Company.

Related to ESMP practices, M15 ranked the questions in the most positive structure. This case mostly focused on the Development part of the questionnaire. There for the best practices in affecting the supply base to embrace waste counteractive action strategies is Development. It is good to mention that M15 was related to Saipa Yadak Company. This company is also an automotive industry and has a close competition with IKID in Iran. In addition, the best practice qualities the consideration of ecological worries into its inventory network administration to the improvement of procurement policy. This manager corresponds as often as possible with its suppliers and guarantees a consistent dialog for information trade and observation. The best practice has actualized the ISO14001 standard and is included in consistent change programs. Moreover, no motivations are utilized; despite the fact that this case trusts that it can have an effect. These specific factors may have been the key elements to induce the sustainable supply management practice in the company.

5. Discussion

Many researches related to the environment have been done in which the most of them emphasized the critical role of supply chain and the importance of accurate assessment of suppliers by companies to avoid waste and environmental protection. (Berdien, 2014) has assessed the effect of ESMP on waste reduction at the shipyard industry. The results of this research show that supplier development in spite to supplier selection has the most effect on waste prevention.

In general talking, we can infer that supplier choice might include several and diverse form of criteria, mix of distinctive choice models, cooperative choice making and different types of instability. It is hard to locate the most ideal approach to assess and select supplier, and organizations utilize an assortment of diverse routines to manage it. In this case, in order to choose the right supplier, the most critical issue is considered during the supplier choice.

In order to contribute to the theory, in this research, an empirical test that feasibility of ESMP on environmental activity is considered in the view of multiple managers within a car manufacturing industry and its related and unrelated suppliers.

This research endorses that supplier incentives are preferred to promote waste prevention in supply chain. Conversely, supplier evaluation is seen as the lowest stimulus to promote waste prevention along supply base. Furthermore, in contrast with recent researches still, the old transaction methods are not substitute for proper management of resource which can leading to waste reduction. Then again, this might not be true for all industries.

Although evaluation and selection are seen as two actions that should be run together before other practices, supplier evaluation compared with selection practice is more limited. The selected cases rank evaluation as a more effective practice to promotion of waste prevention.

Due to unavailability of required resources, separation of wastes with different materials was not possible. In addition, since senior managers are more capable and more informed in comparison with other employees, they were preferred to answer the questionnaire. Sample size of this research is little because of points of limitation in time, as well as eagerness and accessibility of case respondents. Also, a bigger or more particular specimen concentrated on the die industry is required.

This study can be considered in various industries for instance it can be effective in prepared food industry or medical industry that delivery time and generally role of suppliers are very important. Although, this apply has already been discussed in the shipbuilding industry. Since, the industries mentioned above are primarily B2C also they are in direct contact with customers and are more responsible toward social and environmental. Hence the focus of this kind of companies is different with companies such as IKID (which is B2B). Second, the result of the cases that have run ESMP can be compared with the result of the cases that have not implemented. Moreover, in further research instead of only qualitative method, quantitate method or combination of qualitative and quantitate can be implied. Also, the effect of variables could be concentrated into more noteworthy point of interest. Subsequently, it may be significant to research whether the foundation or (force) status of corporate leaders has an impact on the likeliness that ESMPs are embraced, whether at the central company or at the suppliers.

6. Conclusion

Various numbers of managers state that in order to reach sustainable supply chain system and waste prevention, ESMP has a positive impact on the upstream chain. However, some ESMP were illustrated to have a better impact than other practices. This conclusion indicates which practices are preferred in order to motivate suppliers to waste prevention and protect environment. Also the roles of variables are explained. Subsequently, answering the general research question: How can waste prevention promote supply upstream in the car manufacturing industry.

Based on the achievements in data analysis, the conceptual model can be more accurately investigated as follows: possibility of the supplier evaluation in order to promote the appropriation of waste prevention strategies at the upstream chain is less effective than other practices as illustrated in the figure 3 in red color. Conversely, development with green color followed by incentives and selection are discovered to be fundamental or essential encouragements for suppliers.

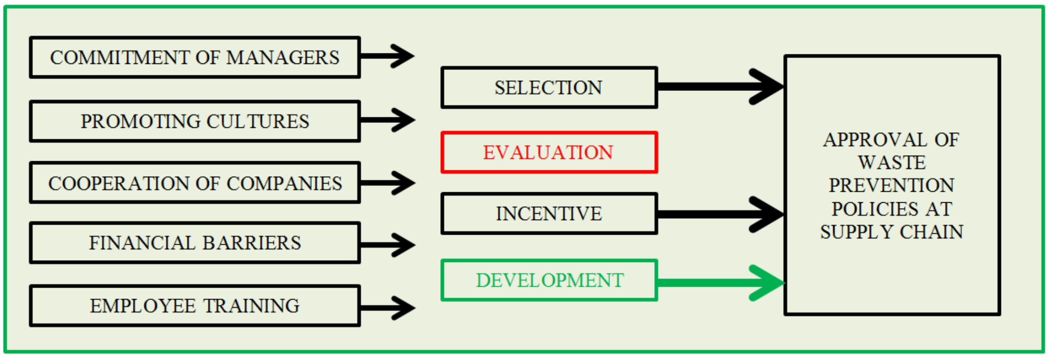


Figure 3: Modified conceptual model

It should be noted that in the view point of top managers, incentives and principally financial incentives are primarily approved for changing supplier perspective. Generally considering environmental practices, various factors are discovered to influence of environmental supply chain practices.

One of these factors is commitment of managers to environmental issues to aim of waste prevention. In addition, promoting culture in the field of supply management and awareness of managers about prevention of waste not only has a positive effect on environmental issues but also, increase net income and reduce costs. However, cooperation of companies to implement the process of waste prevention could play a very important role.

Furthermore, regarding to development of the supply chain, there is a gap between current system and potential system that is expected to be implemented. The current exposure is based on the transaction. Whereas, supplier development is considered as a significant factor to progress environmental performance, still environmental issues are not priorities in most of companies. While large numbers of companies focused on financial profits and lower cost and in their opinion, ESMP is looked as a cost and a limitation of run. However, association with social responsibility can promote supply chain under consideration of waste prevention.

Moreover, with comparison of related suppliers and unrelated suppliers and by considering the fact that P value of selection and incentive is less than 0.05 it can be concluded that there are significant differences between these two practices which association of them with ESMP should be reconsidered. Eventually, with the integration of three factors mentioned above, the supply chain can be improved to achieve the common interest in the field of environmental.

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Appendix (1): calculation needed for table 4

	Managers	ESMP				Barriers		
		Selection	Evaluation	Incentives	Development	behavioral	structural	economic
Internal respondents	I M1	3.6	3.0	4.0 (1/2X)	4.0 (1/2X)	4.5	-	-
	M2	4.0 (1/3X)	3.5	4.0 (1/3X)	4.0 (1/3X)	3.7	-	-
	M3	4.0	4.0	5.0 (1/2X)	5.0 (1/2X)	4.5	-	-
	M4	4.6 (X)	4.5	4.0	4.0 II	1.5	-	-
	M5	3.0	2.5	4.0 (X)	2.0	3.0	-	-
	M6	3.0	4.0 (1/2X)	4.0 (1/2X)	3.0	3.5	-	-
	M7	3.0	2.5	4.0 (X)	2.0	3.0	-	-
	M8	4.3 (X)	4.0	4.0	4.0	5.0	-	-
	(%) |>=3 (ESMP) |=<3 (Barriers)	100	75 III	100 V	75	37.5	-	-
	IV # of manager's 1st score	2.3(29%)	0.5(6%)	3.8(47%)	1.3 (16%)	-	-	-
External Respondents	M9	3.6	4.5 (X)	4.3	3.5	3.7	VII 3.6 (Y)	4.0
	VI M10	2.6	3.5	4.0 (1/2X)	4.0 (1/2X)	3.5	3.0 (1/2Y)	3.0 (1/2Y)
	M11	2.6	4.3 (1/2X)	4.3 (1/2X)	4.0	3.7	3.0 (1/2Y)	3.0 (1/2Y)
	M12	3.6	4.0	4.3 (X)	3.5	4.5	4.0	3.0 (Y)
	M13	2.4	4.3	4.0	4.5 (X)	-	-	-
	M14	3.4	3.5	4.3	4.5 (X)	-	-	-
	M15	4.8 (1/2X)	4.8 (1/2X)	3.7	3.5	3.2 (Y)	3.6	4.6
	M16	4.0 (X)	3.3	3.3	3.5	3.6	3.3 (Y)	3.6
	M17	3.6	3.5	3.7 (X)	3.5	3.5	3.0	1.6 (Y)
	M18	4.6 (X)	2.5	2.0	4.5	4.5	4.3	3.3 (Y)
	M19	4.5 (X)	3.5	2.7	3.5	-	-	-
	M20	4.0	2.8	1.7	4.5 (X)	-	-	-
	(%) |>=3 (ESMP) |=<3 (Barriers)	75	83	75	100	0	37.5	50
	# of manager's 1st score	3.5 (29%)	2 (17%)	3 (25%)	3.5 (29%)	1 (12%)	3 (37%)	4 (50%)
Overall Score	(%) |>=3 (ESMP) VIII |=<3 (Barriers)	85	80	85	90 IX	18.75	37.5	50
	# of manager's 1st score	5.8 (29%)	2.5 (12%)	6.8 (39%)	4.8 (24%)	1 (12%)	1 (37%)	1 (50%)

I. The average of answers to the questions 5,6,7,8 and 9 by M1

II. Total number of first scores given by M1 to M8 for Incentive practice

III. Number of Internal man-agers who ranked more than or equal 3 for selection related questions.

IV. It is the summation of Xs in selection column where X=1.

V. percent of managers who ranked highest scores for Eva-luation practice. 0.5/8(managers) = 0.06 = 6%

VI. The highest score given by manager 10 for the specific pr-actice. If like this case the highest score given to two pr-actices each one will get the half credit.

VII. The lowest score given by manager 11 for the specific practice. If like this case the lowest score given to two practices each one will get the half credit.
VIII. Calculated by formula (1)
IX. Calculated by formula (2)

Appendix (2): Questionnaire of the study

Subject	Question	Type
General info (external cases)	Company:	Open
	Date:	Open
	Interviewee job function:	Open
	Company size/number of employee:	Open
	Plant size number of employee:	Open
	Number of suppliers:	Open
Company (external cases)	1. Does your company have an environmental policy?	Likert-type
	2. To what extend do you consider the environmental policy to be proactive?	Likert-type
	3. To what degree is waste prevention a priority within the environmental policy?	Likert-type
	4. Is your company ISO14001 certified?	Binary
Selection	5. To what extent does supplier selection play a role with regards to waste prevention?	Likert-type
	6. To what degree it is necessary to include waste prevention criteria in supplier selection?	Likert-type
	7. To what degree should suppliers be required to have an environmental management system?	Likert-type
	8. To what extent are suppliers asked to commit to your waste reduction goals?	Likert-type
	9. To what degree is waste prevention important in supplier selection?	Likert-type
Evaluation	10. Supplier evaluation to have an impact on the supplier's performance?	Likert-type
	11. Can supplier evaluation on environmental performance play a role in reducing waste?	Likert-type
	12. To what extent are suppliers scored on their environmental performance?	Likert-type
	13. To what extent do you provide feedback to suppliers about results of the evaluation?	Likert-type
Incentives	14. Can you motivate suppliers by means of incentives to improve their environmental performance?	Likert-type
	15. To what degree do incentives on waste prevention impact the suppliers' environmental performance?	Likert-type
	16. To what degree do you promise (consideration for) future business?	Likert-type

Development	17. To what extend do you believe that collaboration can engage suppliers in waste prevention?	Likert-type
	18. To what extent do you collaboration with suppliers on waste prevention?	Likert-type
Barrier type 1 (Behavioral)	19. To what degree do you perceive (higher) management to be committed to waste prevention?	Likert-type
	20. To what extent are the purchasing personnel aware of the environmental impacts of purchased supplies?	Likert-type
	21. Is training of personnel seen as important?	Likert-type
	22. To what extent do you experience awareness of suppliers on the environmental impact of their products?	Likert-type
Barrier type 2 (Structural)	23. To what extent do you consider the environmental policy to be proactive?	Likert-type
	24. To what degree is waste prevention a priority within the environmental policy?	Likert-type
	25. To what extent have processes been redesigned to reduce waste?	Likert-type
Barrier type 3 (Economic)	26. To what extent do you (expect to) face lower costs?	Likert-type
	27. To what extent do you (expect to) reduce the amount of waste?	Likert-type
	28. To what extent do you (expect to) reduce the cost of purchasing?	Likert-type

Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Wind Farm Layout Optimization to Reduce Noise

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Abstract

Energy is a fundamental component of socio-economic development and economic growth. Renewable energy sources like wind energy is indigenous and can help in reducing the dependency on fossil fuels. In recent years, electricity generation from wind energy has shown a growth all over the world. The most important challenge of wind power industry which has a negative health impact on human beings is the noise produced by wind turbines. The sources of sounds emitted from operating wind turbines can further be divided into two categories as mechanical sounds and aerodynamic sounds. Noise problem can be minimized by effective facility design and selection of equipment. Wind power in Turkey is gradually expanding in capacity, mainly in the Aegean and Marmara regions. The aim of this research is to evaluate candidate areas to establish a wind farm, to find out the number and the type of turbines for each wind farm, while minimizing the exposed noise level using a layout optimization model. The results of this study illustrates the effect of constrained and continuous-variable multi-objective optimization layout, total cost and noise on trade-off between wind turbine positioning and noise reduction.

Keywords: Wind power, Wind turbine, Renewable Energy, Positioning, Environment

1. Introduction

Wind energy is the fastest growing source of renewable energy. The generations of power by wind energy are obtaining a considerable attention as an alternative to conventional fossil, coal or nuclear sources (Anicic et al., 2016). Wind turbines transform wind energy into electric energy without producing any waste. However, they make noise due to the rotational motion of the wind turbine blades. Solving the Wind Farm Layout Optimization Problem (WFLOP), which consists in optimally positioning the turbines within the wind farm, is another important phase of a wind farm design (Samorani, 2013).

In recent years, electricity generation from wind energy has shown a growth all over the world. Wind turbines transform wind energy into electric energy but they make noise due to the rotational motion of the wind turbine blades (Lee & Lee., 2014). Wind turbine (WT) noise effect can be considered as one of the main technical issue to the implementation of WT. Wind turbine has two major noise components, mechanical and aerodynamic noise (Son et al., 2010). The noise production of wind turbines has a negative health impact on human beings (Saidur et al., 2011). There are several factors which effect noise of wind farms such as tunnel effect (turbulance), blade's shape etc. Landform can be cause of Tunnel effect so this should be bearing in mind while taking wind farm location decision (Ağçay, 2007). The layout optimization is also important because of the wake effect (Herbet et al., 2007). The turbines should be located according to wind direction while wind farm (WF) layout optimization is to find the optimal positions of wind turbines (WTs) inside a wind farm (Chen, 2013). During the location decision the aesthetic pollution factor of turbines and the turbine blades possible damage of local widlife (sometimes birds have been killed by flying into the rotors) should be also taken into consideration (Saidur et al., 2011).

Wind Energy is clean flue source and domestic source of energy, and wind power is one of the lowest priced renewable energy technologies available. Wind turbines can be built on existing farms or ranches. Farmers and ranchers can continue to work the land because the wind turbines use only a fraction of the land (Saidur et al., 2011). Wind power plant owners make rent payments to the farmer or rancher for the use of the land. This greatly benefits the economy in rural areas (Saidur et al., 2011). Wind energy is clean, environmental friendly, and cheaper compared to other sources of renewable energy. The usage of wind energy compared to petroleum based power plants that produce energy could also reduce water consumption (Saidur et al., 2011). The minimal impact on habitat that is compared to other sources of energy is known wind energy. Minimizing many of negative impacts is possible with carefully wind turbine design, wind turbine plan, wind farm location decision.

Wind farms are being installed in several countries to produce energy from renewable resources. However, the noise that they produce has a major drawback on human health. The severity of land form, blade's shape, noise limits, wind speed, power of wind turbines, distances between wind turbines, proximity to residental area constraints influence noise production from wind turbines. Noise problem can be minimized by controlling those factors. This study considerscost optimization forlow noise level wind farms according to actual wind and territory information, and improving cost factors which are recommended by the low wind speed technology projects. Thus, this study, aims to minimize the noise level exposure on human beings by the wind farms considering the total cost incurred.

Wind turbines use renewable and environment friendly resource - the wind - to produce electricity. Therefore, the noise produced by wind turbines is a contentious issue. Prolonged exposure to industrial noise can elevate stress, increase workplace accidents rates, and stimulate aggression and other anti-social behaviors among humans. Therefore, this research aims to evaluate candidate areas to establish a wind farm, to find out the number and the type of turbines for each wind farm, while minimizing the exposed noise level using a layout optimization model.

2. Literature Review

The noise pollution that wind turbines create is a major disadvantage of using wind turbines. This noise can exert a negative influence on people near wind turbines (Lee & Lee, 2014). Noise emitted by a wind turbine can be divided into mechanical and aerodynamic types (Son et al., 2010). Mechanical noise is produced by the moving components such as gear box, electrical generator, and bearings. Normal wear and tear, poor component designs or lack of preventative maintenance may all be factors affecting the amount of mechanical noise produced. Mechanical noise can be minimized at the design stage (side toothed gear wheels), or by acoustic insulation on the inside of the turbine housing (Saidur et al., 2011). Mechanical noise can also be reduced during operation by acoustic insulation curtains and anti vibration support footings. Aerodynamic noise is developed by the flow of air over and past the blades of a turbine. Such a noise tends to increase with the speed of the rotor (Saidur et al., 2011). Lower blade tip speed results in lower noise levels. The particular concern is the interaction of wind turbine blades with atmospheric turbulence, which results in a characteristic “whooshing” sound (Aninic et al., 2016). The manufacturers can minimize aerodynamic noise by careful design of the blades. Table 1 shows the summary of the literature review.

Table 1: Summarizing Table of Literature Review

Author andYear	Consideration of Research
Ağçay 2007	Wind power energy and wind turbines, where estimated of Turkey’s electric power demand, the design of a wind farm and set of cost of a wind farm is studied.
Anicic et al. 2016	Noise evaluation of wind turbine by soft computing methodologies and also done a comparativestudy.
Anthony et al. 2004	The noise issues of wind turbine by renewable energy search laboratory center for energy efficiency and renewable energy is done.
Baath 2013	An objective method is developed to measure sound levels in forest also describes a newly designed and constructed a field qualified data acquisition system to measure spectra and total noise level of sound from wind turbines.
Chen 2013	Chen does wind farm layout optimization under uncerainty with landowners’s financial and noise concerns.
Chen and Macdonald 2014	Chen and Macdonald used land owner modeling to optimize a system level cost of energy wind farm layout optimization.
Feng and Shen 2015	Feng and Shen used random search algorithm for solving the wind farm layout optimization problem.
Hammad et al. 2016	The construction site of layout planning for minimizing noise pollution is done and transport cost is modeled with a multi- objective mixed integer non linerar programming model.
Jensen 1983	Jensen's far wake model.
Katilass et al. 2016	Katilass et al. analyzed the wind turbine noise’s impact on the environment and emission.
Lee et al. 2014	Lee et al. evaluated the aerodynamic noise generated from a small wind turbine based on a 10 kw wind turbine.
Nikolić et al. 2016	Nikolić et al. studied the estimation of noise levels at wind turbines by potential of neuro fuzzy methodology.
Onakpoya et al. 2015	Onakpoya et al. studied the effect of wind turbine noise on sleep and quality of life also do a systematic review and meta-analysis of observational studies.

Renkema 2007	The comparison of different far wake models shows that the Jensen's far wake model is a good choice to solve the wind farm layout problem due to its simplicity and relatively high degree of accuracy.
Renkema 2007	Renkema used wind farm data and wind tunnel measurements for validation of wind turbine wake models.
Saidur et al. 2011	Saidur et al. studied the wind energy's enviromental impacts.
Samorani 2013	Samorani reviewed the wind farm layout optimization problem and give an overview on the existing work.
Serrano et al. 2010	Serrano et al. studied the wind turbines layout optimization by using an evolutive algorithm.
Shakoor et al. 2015	Shakoor et al. used area dimensions and definite point selection techniques for wind farm layout optimization.
Shakoor et al. 2016	Shakoor et al. reviewed the wake models in general and far wake models in particular.
Shaltout et al. 2015	Shaltout et al. constructed tradeoff analysis of energy harvesting and noise emission for distributed wind turbines.
Son et al. 2010	Son et al. studied an integrated numerical method for the prediction of wind turbine noise and the long range propagation.
Sorkhabi et al. 2016	Sorkhabi et al. conducted a constrained and continuous-variable multi-objective optimization problem including land-use and proximity constraints that considers energy and noise as its objective functions,based on Jensen's wake model and the ISO-9613-2 noise Standard.
Tingey et al. 2015	Tingey et al. used sound pressure level constraints wind farm layout optimization.
Vogiatzis and Vanhonacker 2015	The noise reduction in urban LRT Networks is done by combining track based solutions.

3. Model

In this study, founding problem of the wind farm is tackled. There are different candidate areas for founding wind farm. The initial and operational costs that will occur over the planning horizon exist during to founding wind farm for each candidate areas. The average wind speed and distance to nearest residential area of each candidate area are known. The wind turbine has different size and specifications. The initial and operation cost that will occur over the planning horizon is exchangeable for each type of turbine. The amount of electricity production and noise emitted by wind turbine is known for each type of turbine in founding each candidate area. The minimum requirement distance between two turbines is known for each type of turbine. Budget is determined for initial costs. The noise emission from wind turbine's level can not reach the negative effector level on people's health who lives nearest residential area. Determination of candidate areas for founding a wind farm, number and type of turbines for each wind farm, and location for all used turbines should satisfy the maximum net present value during over a planning horizon, less initial cost than budget, and less noise level than limited level at nearest residential area.

Assumptions:

- Only one type of turbine can be set up in each field.
- Fields is rectangular and homogenous. (There is no factor such as trees, roughness that will cause different wind speed at different points in the field.)
- The average distance between closest residental area and candidate area are used for calculating the noise level at the residental areas located in the vicinity of wind farms.

Parameters:

A: Set of candidate areas (1, 2, 3… |A|)
T: Set of tubine types (1, 2, 3...|T|)
T_a: Requirement wind speed for turbine's operation and set of availability turbine types when wind speed at candidate area *a* is considered.
F_{at}: Total initial cost of a type *t* wind turbine's foundation at candidate area *a*.
V_{at}: Net present value of a type *t* wind turbine's cost at candidate area *a* during over the planning horizon (maintenance, electricty transfer etc.).
R_{at}: Net present value of a type *t* wind turbine's revenue at candidate area *a* during over the planning horizon.

D_a: Average distance between nearestresidental area and candidate area *a* (km)
Ax_a: Length of candidate area *a*, in the horizontal X direction.
Ay_a: Length of candidate area *a*, in the vertical Y direction.
Dis_t: Minimum distance between same type wind turbines.
M_a: Total initial fix cost of foundation at candidate area *a* (purchase or deposit, first rent, transportaion way's construction, etc.)
N_a: Net present value of total variable foundation costs at candidate area *a* during over the planning horizon (area rent, cleaning, way maintenance, etc.).
B: Budget for all initial costs
H_{at}: Maximum number of type *t* wind turbines, located in candidate area *a*.
L_t: Emitted noise level by a type *t* wind turbine. (dB)

Decision variables:

x_{iat}: X coordinate of i^{th} type *t* wind turbine at candidate area *a*.
y_{iat}: Y coordinate of i^{th} type *t* wind turbine at candidate area *a*.
U_{iat}: Equals one if i^{th} type *t* wind turbine is used at candidate area *a*, otherwise equals zero.
Z_{at}: Equals one if type *t* wind turbine is used at candidate area *a*, otherwise equals zero.

$$Max\, TP = \sum_{a\in A}\sum_{t\in T_a}\sum_{i=1}^{H_{at}}(R_{at} - F_{at} - V_{at})U_{iat} - \sum_{a\in A}\sum_{t\in T_a}(M_a + N_a)Z_{at}$$

$s.t.$

$$x_{iat} \le Ax_a U_{iat} \qquad \forall a \in A, t \in T_a; i = 1,\dots,H_{at} \qquad (1)$$

$$y_{iat} \le Ay_a U_{iat} \qquad \forall a \in A, t \in T_a; i = 1,\dots,H_{at} \qquad (2)$$

$$U_{iat} \le Z_{at} \qquad \forall a \in A, t \in T_a; i = 1,\dots,H_{at} \qquad (3)$$

$$\sum_{t\in T_a} Z_{at} \qquad \forall a \in A \qquad (4)$$

$$(x_{iat} - x_{jat})^2 + (y_{iat} - y_{jat})^2 \ge dis_t^2 Z_{at} \qquad \forall a \in A, t \in T_a; i, j = 1,\dots,H_{at} \mid i \ne j \qquad (5)$$

$$10 * \log_{10}\left(\frac{1}{10}\sum_{t\in T_a}\sum_{i=1}^{H_{at}}(10^{La_t/10})U_{iat}\right) \le 75dB \qquad \forall a \in A \qquad (6)$$

$$\sum_{a\in A}\sum_{t\in T_a}\sum_{i=1}^{H_{at}} F_{at}U_{iat} + \sum_{a\in A}\sum_{t\in T_a} M_a Z_{at} \le B \qquad (7)$$

$$x_{iat}, y_{iat} \ge 0 \qquad \forall a \in A, t \in T_a; i = 1,\dots,H_{at} \qquad (8)$$

$$U_{iat} \in \{0,1\} \qquad \forall a \in A, t \in T_a; i = 1,\dots,H_{at} \qquad (9)$$

$$Z_{at} \in \{0,1\} \qquad \forall a \in A, t \in T_a \qquad (10)$$

In this model, objective function will maximize total profit's net present value over a planning horizon. (1) X coordinate of i^{th} type *t* wind turbine at candidate area *a* field should not exceed length of candidate area *a,* in the horizontal X direction. If type *t* wind turbine is used at candidate area *a,* U_{iat} will be one. If type *t* wind turbine is not used at candidate area *a,* X coordinate of i^{th} type *t* wind turbine at candidate area *a* will be zero. (2) Y coordinate of i^{th} type *t* wind turbine at candidate area *a* field should not exceed length of candidate area *a,* in the vertical Y direction. If type *t* wind turbine is used at candidate area *a,* U_{iat} will be one. If type *t* wind turbine is not used at candidate area *a, Y* coordinate of i^{th} type *t* wind turbine at candidate area *a* will be zero. (3) If i^{th} type *t* wind turbine is used at candidate area *a* then variable Z_{at} will equal to one. If i^{th} type *t* wind turbine is not used at candidate area *a* then variable Z_{at} will equal to zero. (4) At most one type of wind turbine can be use at each candidate area *a*. (5) Minimum distance between same type wind turbines can not be less than lower distance limit. (6) Noise emitted by wind turbine can not exceed the upper limit of 75 dB noise level at the residental area. (7) Total initial cost can not exceed budget. The other constraints determine decision variables types. The noise level is used as 75 dB in this model. The noise level's fuction that ocur at residental area caused by wind farms is given below.

$L_{at} = L_t - K_a$
(11)
$K_a = (20 * \log_{10}\sqrt{D_a} - 8)$ (12)

Equations (11) and (12) have been adopted from Hammad et al. (2016). Equation (11) calculates Lat that is the continuous equivalent sound pressure level, measured at residental due to noise type t wind turbine emitted from candidated area a. Equation (12) measures Ka that is the distance attenuation factor for each candidate area a located away from the nearest residential area.

4. Discussion

In this study, an optimal model is created to reduce the noise level by considering the factors of number of wind turbines, available type of wind turbines, land size and location. This model is designed to reveal optimal positioning of wind turbines in any size of wind farms, selection of the best turbine type for the most productive farms, the best location decision which has low noise level impact to residental areas, the optimal candidated areas which consider available wind speed, the total cost of investments for each type of turbines and each candidated area with considering cost factors (transportation cost, maintenance cost, setup cost, turbine cost, fixed cost for land, cost for land rent, etc.) and total electricty over the planning horizon to generate revenue of one type turbines in a field.

This research also focuses on the studies carried out on wind farm layout optimization problem and the current state of the art of fitness functions used for the optimization of wind farms using Jensen's wake model. Also there are several factors which effect noise of wind farms such as tunnel effect (turbulance), Blade’s shape (Tingey et al., 2015), wind speed, landform etc. So, in this study, wind and territory information were taken into account and the cost factors which are recommended by the low wind speed technology projects were improved and also potential locations were investigated for a wider solution space to be formulated for optimization of low noise level wind farms.

5. Conclusion

Wind turbines use renewable and environment friendly resource, the wind, to produce electricity. Therefore, the noise produced by wind turbines is a contentious issue. Prolonged exposure to industrial noise can elevate stress, increase workplace accidents rates, and stimulate aggression and other anti-social behaviors among human.

This study utilized a layout optimization model to evaluate candidate areas for founding a wind farm, number and type of turbines for each wind farm, and location for all used turbines to satisfy the maximum net present value during over a planning horizon with less initial cost than budget in consideration of noise level which is limited level at nearest residential areas. Thus, this study provides a guidance to establish low noise wind farms, considering the right selection of the type of the turbines and territory, which then will maximize the benefit obtained.

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Biography

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An Empirical Study of Safety Improvement by Risk Management Guidance in Healthcare Organisations

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Medical errors represent a serious challenge and pose a significant threat to patient safety worldwide. In response to the occurrence of medical errors, healthcare organizations develop and implement a range of risk management initiatives. While such initiatives and resources have been allocated to provide the basic foundation to operational decisions for better safety performance, it is still a question whether such resources have generated value and success in the healthcare marketplace. To address this question, risk management guidance documents could provide inference between the prescribed risk management process and the level of medical errors in healthcare organizations.

In this study, we employ a unique dataset from the English National Health Service (NHS) acute trusts to investigate the causal mechanisms in explaining the impact of risk management guidance documents on medical errors. We conduct text-mining techniques on risk management guidance documents to extract data about the nature of the content of documents, while we also use aggregate NHS data to get performance measures. We finally use regression analysis to predict the impact of risk management guidance documents on medical errors. The finding of this study identifies some aspects from the content of risk management documents that may be helpful in the success of risk management to accelerate improvement in patient safety.

Biography

Mecit Can Emre Simsekler is a Research Associate at the UCL School of Management. Emre obtained his PhD from the University of Cambridge in 2014. In addition, he was a visiting researcher in the Center for Medical Innovation System at the University of Tokyo, and in the Center for Patient Safety and Quality Research at Harvard Medical School Boston Children's Hospital. Emre's research activities focus on healthcare management, operations, design and risk management. Emre is a member of the Institute for Operations Research and Management Science (INFORMS), the Manufacturing and Service Operations Management Society (MSOM), Institute of Industrial Engineers (IIE) and Academy of Management (AOM).

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Heuristic Evaluation: Overview and a Proposed Framework with User Experience Perspective

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Abstract

Digital transformation of the industries and expanding use of the Digital System and Products (DS&Ps) substantially increased importance of user performance, satisfaction and preferences. The success of the modern DS&Ps heavily relies on User Experience (UX) and UX has become a key strategic factor in digital industry. Very critical to UX efforts are evaluation methods one of which is Heuristic Evaluation (HE). The HE is the expert review of DS&Ps based on a rule set. The objectives of the HE include identifying usability problems and providing severity ratings as well as improvement suggestions for the identified problems. The HE has been widely used in usability studies as it is low cost, high applicable and effective in detecting usability problems. To offer reliable and useful outcomes for UX evaluation, the HE needs to be restructured. The current study provided an overview of the HE in usability context and proposed a new HE framework with UX perspective. The framework includes the Planning, Evaluation and Delivery (PED) phases and requires understanding of the UX at the strategic level. The current study significantly contributes to the literature through providing researchers and practitioners with a new road map for effective heuristic UX evaluation in the modern digital context.

Keywords

User experience, usability, digital systems, heuristic evaluation

1. Introduction

The world is going digital and so are the industries. While until 90's the digital platforms have been an extension of the real life, today digitalization has expanded to all aspects of business and personal life. The digital transformation in the last decade has made Digital Systems and Products (DS&Ps) crucial to both business and people. Mobile applications, virtual reality, augmented reality, ambient intelligence are examples to innovative digital concepts (Cook et al., 2009; Microsoft Research, 2008; Shneiderman & Plaisant, 2010). Advances in the DS&Ps have been observed to be based on innovative ways of user interaction, and the success of DS&Ps depends on the user performance, satisfaction and preferences (Tapia et al., 2015). Related to the focus on the user, academic studies and industrial reports emphasize that User Experience (UX) has become the key to success of the DS&Ps (Tapia et al., 2015).

UX is the combination of all cognitive, performance related, and hedonic factors that affect the user (Bevan, 2008 & 2009). UX is not a new concept; it is the expansion of usability into modern digital context. As the importance of how DS&P design determines user performance, acceptance and satisfaction has been unfolded, usability has become an important multidisciplinary research area for the last two decades. By definition, usability primarily addresses three dimensions: while *effectiveness* and *efficiency* represent performance related and objective side of usability, *user satisfaction* is highly subjective (Nielsen, 1993; Tullis & Albert, 2008). Various criteria have been used to measure these dimensions. For example, task completion rate, task completion time and subjective ratings are the measures of effectiveness, efficiency and satisfaction respectively. A vast literature explored usability dimensions and importance of usability for success and acceptance of DS&Ps of various kinds (Çalışır & Çalışır, 2004; Davis, 1989; Erdinc et al., 2015). For instance, Technology Acceptance Model (TAM), developed for information technology (IT) context, introduces perceived ease of use (i.e. usability perception) as one of the core components that shapes user intentions and attitudes toward using new technologies (Basak et al., 2015; Calisir et al., 2014; Davis, 1989, Lee et al., 2013). Additionally, perceived ease of use is a determinant of perceived usefulness in that users perceive a system more useful when they do not encounter problems while using it (Davis, 1989). Çalışır and Çalışır (2004) showed the positive effect of the perceived ease of use on the perceived usefulness for the Enterprise Resource Planning

(ERP) systems. In recent years, usability principles have been widely implemented in DS&P design, and usability has evolved into UX concept. While UX and usability have commonalities such as using basically the same set of evaluation methods, they also have significant differences. The first difference is the content. Performance (e.g. success in completing a task under time pressure), as well as the perceptions of users toward the DS&Ps shape UX. Thus, UX covers performance related factors addressed in the usability studies. Additionally, hedonic qualities (e.g. stimulation, feelings such as trust to a web site), which are highly subjective in nature, are important UX elements. Another difference is the role that UX plays in the digital industry. While usability had originated from theoretical and applied human-computer interaction knowledge, UX has been widely explored on the industry side. As the digitalization in business lines and management functions have gained utmost importance for corporate success, UX has become a corporate level issue rather than a design related technical dimension (Tapia et al., 2015). To provide good UX, business goals, priorities and user profile should be thoroughly understood and this understanding should steer the DS&P design.

Evaluation is a core process in system development and improvement. Thus, using effective evaluation methods is crucial to effective UX measurement and improvement of the DS&Ps. Widely accepted usability evaluation methods such as Heuristic Evaluation (HE), user tests and subjective ratings (e.g. surveys, questionnaires) can also be used for evaluating UX (Tullis & Albert, 2008). However, these methods should be adapted to address abovementioned differences of UX to produce thorough evaluations. While some authors developed UX specific evaluation tools such as User Experience Questionnaire (UEQ; Laugwitz et al, 2008), other methods such as HE need to be adapted to be effectively used for UX evaluations.

HE is the expert review of the DS&Ps based on a pre-determined rule set. As it is a, low cost, effective and highly applicable method, the HE has been widely preferred to evaluate usability by both researchers and practitioners (Aitta et al., 2008; Hasan et al., 2012; Jaferian et al., 2014; Nielsen, 1993; Skov & Stage, 2012; Torrente et. al., 2013). The HE outputs include descriptions of the detected usability problems, as well as severity rating and improvement alternatives for the identified problems. Some studies extended the HE to address UX by developing heuristic rule sets (Väänänen-Vainio-Mattila & Wäljas, 2009). Solely extending heuristic rule sets could add limited value to evaluation effectiveness as the expanding role of UX necessitate a broader adaptation.

The objective of the current study is twofold. First, an overview of the current HE methodology in usability context is presented. Second, a new HE framework that incorporates UX aspect, namely Plan-Evaluate-Deliver (PED) framework, is proposed. The PED framework is expected to provide researchers and practitioners an applicable road map for effective UX evaluations in the modern digital context.

2. Overview of the HE in usability context

The HE is arguably the most applicable usability evaluation method, which made it widespread among the researchers and practitioners (Kirmani, 2008). Kirmani, (2008) showed that 76% of the usability experts were applying the HE for evaluations. The HE basically includes evaluation of a DS&P by a group of experts and detection of usability problems based on an agreed-upon rule set. The objectives of the HE are; i) reviewing different aspects of usability for a DS&P, ii) to identify usability problems, iii) to grade the identified problems based on their significance for user and system performance, and iv) to propose improvements for the identified problems. Hence, the HE outputs typically include usability problem descriptions, severity ratings and proposed solutions for the identified problems. The foremost strengths of the HE include; short time needed to get evaluation results, which is highly preferable under time pressure in business settings, saving effort to find user test participants and its low-cost (Jaferian et al., 2014; Skov & Stage, 2012). The HE has been applied to various DS&Ps such as online libraries (Aitta et al., 2008), IT security management systems (Jaferian et al., 2014), web sites (Torrente et al., 2013) and e-commerce systems (Hasan et al., 2012).

The components of the HE are; a) evaluators, b) heuristic rule set, c) problem severity ratings and d) evaluation method. While a single expert can perform the HE, the recommended practice is to employ a team of evaluators to detect as many usability problems as possible and to cross-validate each expert's findings. Nielsen (1993) suggested that number of the identified usability problems significantly increases when a group of five experts are employed in comparison to evaluation by a single expert. Nevertheless, working in teams can bring challenges such as establishing agreement among the evaluators on the problem definitions, severity ratings (Molich et.al., 2013) and improvement suggestions.

The heuristic rule sets include principles of good usability for the DS&Ps under evaluation. The rules are based on theories and applications of human-computer interaction and usability. Jaferian et.al. (2014), propounded three approaches in determining heuristic rules: Bottom-up (i.e. developing rules based on qualitative data collected to understand system characteristics), Top-down (i.e. developing rules based on high level expert opinions and theories), and hybrid (i.e. validation of rules which were developed in bottom-up manner by using the theories) approaches. The evaluators can either use the existing rule sets or develop system-specific rules for particular DS&Ps. The most traditional generic rule set in usability context is "Nielsen's ten heuristics", which is applicable to a range of DS&Ps (Nielsen, 1993). "Shneiderman's eight rules for interface design" is another generic rule set (Shneiderman & Plaisant, 2010). Some researchers extended the existing rule sets. For instance Chen & Macredie (2005) added three rules to Nielsen's ten heuristics to address particularities of e-commerce web sites. Specific rule sets have been developed for many DS&Ps such as online libraries (Aitta et al.,2008), IT security management systems (Jaferian et al., 2014), web sites (Torrente et al., 2013) and e-commerce systems (Hasan et al., 2012). Table-1 presents examples to generic, extended and system-specific rule sets.

Table-1: Examples to heuristic rule sets

Reference	Heuristic rules	Reference	Heuristic rules
Nielsen (1993)	*Visibility of system status *Match between system and real world *User control and freedom *Consistency and standards *Error prevention *Recognition rather than recall *Flexibility and efficiency of use *Aesthetic and minimalist design *Help users recognize, diagnose and recover from errors *Help and documentation	Jaferian et al. (2013): IT Security Management Tools	*Visibility of activity status *History of actions and changes on artifacts *Flexible representation of information *Rules and constraints *Planning and dividing work between users *Capturing, sharing, and discovery of knowledge *Verification of knowledge
(Chen & Macredie, 2005): additions to Nielsen's rules for e-commerce web sites	-Support and extend the user's current skills -Pleasurable and respectful interaction with user. -Protect the personal information.	Shneiderman & Plaisant (2010)	*Strive for consistency *Cater to universal usability *Offer informative feedback *Design dialogs to yield closure *Prevent errors *Permit easy reversal of actions *Support internal locus of control *Reduce short term memory load
Hasan et al. (2012): e-commerce web sites	*Layout of the page *Comprehensibility and ease of interaction *Control and feedback *Multimedia elements *Search *Help *Architecture and navigation *Content *Accessibility and customer service *Design *Purchasing process	Torrente et al. (2013): Web sites	*General aspects *Identity and information *Structure and navigation *Labeling

The end goal of the HE is to propose improvements that can minimize the adverse effects of usability problems. In the industrial context, resources (e.g. designer time) for improvement efforts are always limited and it might be neither efficient nor doable to address all of the identified problems. Hence, prioritizing the problems based on their impact on the system and user performance, which eventually translates into business performance, becomes crucial. Experts' effort to pinpoint as many problems as possible without prioritization can alleviate the usefulness of the HE effort. Thus, providing severity ratings for each problem has been found necessary and researchers used variety of both verbal (Kirmani, 2008), and numerical severity ratings (Chen & Macredie, 2005; Nielsen, 1995; Torrente et al. 2013). Table-2 shows examples to severity ratings.

Table-2: The severity rating examples

Reference	Severity ratings for usability problems
Kirmani (2008)	*Showstopper *Major issue *Irrtiant
Torrente et al. (2013)	1:Minor 2:Moderate 3:Major 4:Critical
Chen & Macredie (2005), Nielsen (1995)	0: Not a usability problem at all 1:Cosmetic problem only 2:Minor usability problem 3:Major usability problem 4:Usability catastrophe

In the conventional HE practice, experts perform evaluation individually and the outputs are then reviewed and compiled into an evaluation report. The experts can adopt different evaluation approaches. Chen and Macredie (2005) highlighted two main approaches as *task based* and *free flow.* In the *task based* evaluation the experts are given scenarios and they are expected to detect problems that a typical user would encounter while carrying out the task in the scenario. In the *free flow* evaluation, the experts are expected to provide an overall evaluation based on the rule set. It can be argued that the *task based* evaluation would be more effective for the DS&Ps that involve extensive user interaction.

The researchers and practitioners can have different perspectives on the HE applications. The researchers could prefer to adopt a quantitative approach and produce numerical outcomes based on mathematical algorithms (Kirmani, 2008; Torrente et al., 2013). Kirmani (2008), developed Heuristic Evaluation Quality Score (HEQS) to measure the quality of the HE practice. Torrente et al. (2013) developed SIRIUS, a method to quantify the usability level of the web sites based on the HE results. The practitioners, on the other hand, can prefer a qualitative approach, and seek to detect problems that pose significant effects on user performance, as well as to produce actionable improvement suggestions which will have greater value for the industry. While research oriented quantification methods could be cumbersome to apply in natural industrial settings with resource and time constraints, solely practice oriented applications can lack a sound technical and scientific basis.

3. The need for a new HE framework for UX evaluation

A significant need was observed to structure and extend the current HE into the Heuristic UX Evaluation (HUXE) framework to address the abovementioned differences of UX in modern digital context. Application of this new framework can culminate in multiple benefits. First, comparative UX studies would be possible across different DS&Ps. Secondly, using this framework will create a knowledge base on the typical problems encountered in using specific DS&Ps (e.g. mobile applications) by certain user groups. Next, following a step-by-step framework will allow a thorough UX evaluation and will be less time consuming, which will substantially contribute to efficiency in DS&P development and improvement process. Finally, this framework will not only address DS&P design but will instill strategic UX perspective to the evaluation process which will meet both business goals and research needs in the current digital context.

4. The Plan-Evaluate-Deliver (PED) framework

The PED framework introduces a three-phase process for the HUXE efforts; Planning for the evaluation, Evaluation, and Delivery of the outputs. The steps of these phases are shown in Figure-1 and described in the following.

4.1 Planning phase

- **Understand business and DS&P development goals and priorities**: The Planning phase is the core part of the HUXE effort. Planning for the HUXE should start with understanding business and DS&P development goals and priorities (Garrett, 2011). Business priorities can determine the importance of different aspects of UX. Additionally, evaluation of particular parts (e.g. modules of ERP systems) of a DS&P can have precedence over other parts. Business and DS&P development priorities should be well defined in the Planning phase so that the evaluation effort can be administered efficiently. While industry is led by business goals (e.g. profitability), research oriented DS&Ps can be developed for different goals and perspectives (e.g. enhancing mobile learning). Only through a solid understanding of the business and DS&P development goals and priorities the evaluators can delineate significant problems. To that end, the target user group should be well defined as the UX needs can vary across different user groups (Garrett, 2011). Thus, effective communication with business stakeholders and DS&P developers to have a common ground for the goals and priorities is imperative in the Planning phase. UX Models, such as Garrett's *Five Elements Model* can be used as a basis to identify business and DS&P development goals and priorities, as well as the profile of the user group (Garrett, 2011).

- **Set the baseline:** When the business and DS&P development goals and priorities are well understood, the evaluators should be able to define what will constitute a UX problem for the DS&P under evaluation. At the baseline, the evaluators should have common understanding about the characteristics of the target user group, the objectives of the evaluation, and the definition of a UX problem.
- **Form the team:** Although a single expert can apply the HUXE, the evaluation will be more effective through a well-managed team effort. The experts are naturally expected to have experience in the evaluation process and in the field where the DS&P under study is used. The DS&Ps are constantly evolving and users as well as evaluators can have different perspectives on the new digital systems. Particularly for the novel DS&Ps, involving young evaluators who have an inherent understanding the needs and behaviors of current user population, would contribute to evaluation effectiveness. Depending on the DS&P under study, it is recommended that the expert team include experts from different age and experience groups.
- **Determine the scope of evaluation:** The scope of the HUXE should be clearly defined so that the evaluators can concentrate on the essential aspects of the system in line with the evaluation objectives. The business/DS&P development goals and priorities should be considered in shaping the scope of the evaluation. As Chen & Macredie (2005) elaborated, mainly three approaches can shape the scope of evaluation:
    - *UX check-up*: The evaluators can apply the heuristic rules to detect UX problems in free flow.
    - *System-based*: The evaluation can focus on certain parts of the DS&P.
    - *Task-based*: The evaluators can play the role of a typical user and try to identify usability problems that the users would encounter while performing a specific task.

All three approaches above can serve to identify UX problems. While UX check-up offers an overall look to the system, the system or task based approaches allow for specific and systematic evaluations.

- **Select/Develop heuristic rule set:** The heuristic rule set is the main tool for the HUXE effort. The rule set should: i) fit the scope of the evaluation, ii) be descriptive, iii) address hedonic factors as well as usability dimensions, iv) provide concrete guidance to identify UX problems. The experts can select an existing rule set (Nielsen, 1993; Shneiderman & Plaisant, 2010), extend the rule sets (Chand & Macredie, 2005), or develop a system-specific new rule set (Aitta et al., 2008; Hasan et al., 2012; Jaferian et al., 2014; Torrente et al., 2013). UX Models (e.g. Garrett's *Five Elements Model,* Garrett, 2011) and UX tools (e.g.UEQ by Laugwitz et al, 2008) would be helpful resources in developing rule sets.

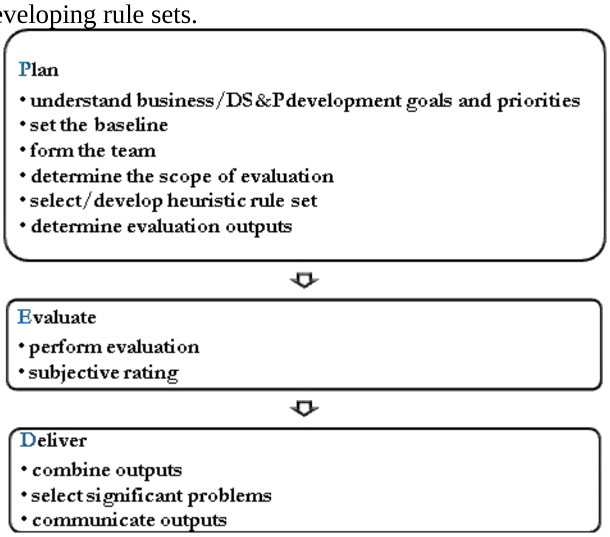

Figure-1: The PED framework

- **Determine evaluation outputs:** The value of the HUXE effort heavily relies on its outputs. The outputs should provide system developers and designers with a guide line to improve the DS&P under evaluation. Therefore, the outputs should include UX problem descriptions and severity ratings, as well as concrete improvement suggestions for the identified problems. In addition to conventional outputs, the PED framework proposes that collecting perceived UX ratings among the evaluator team will serve to address subjectivity of the UX and add value to the evaluation effort. The proposed PED outputs are described in the following.

o *UX problem descriptions*: The problems should be articulated explicitly, and the description should indicate: i)the rule that the problem violates, ii) the impact of the problem on user performance, satisfaction or preferences. Visuals (e.g. screenshots) should be used extensively to communicate problems effectively.

o *Problem severity ratings:* It is important to distinguish between the problems; while certain problems severely alleviate user performance and satisfaction (e.g. impeding task completion), other problems could be cosmetic and would have low priority in resource allocation for improvements. Academic studies can require examination of all identified problems regardless of their severity levels. In business settings, each corrective action on the identified problems would consume valuable resources. In order to guide the improvement efforts, it is important to grade problems based on their impact. The rating scale should be applicable among the evaluator team and sufficiently descriptive so as to differentiate between the problems (Molich et al., 2013). The PED framework proposes the three-level severity rating scale below, which grades the problems based on their impact on usability dimensions (i.e. effectiveness, efficiency, satisfaction) and UX aspect (i.e. hedonic factors).

Table-4: Problem severity rating scale

Level	Description
Severe	Significant impact on effectiveness /hedonic factors. Impedes task completion. Definitely changes user preference. Should be fixed immediately.
Moderate	Adverse effect on efficiency / satisfaction / hedonic factors. Leads to poor user performance or poor satisfaction. Adversely affects user preference. Should be fixed eventually.
Minor	Cosmetic. Partial effect on user performance. Should be fixed when resources allow.

o *Improvement suggestions:* The evaluators should provide detailed improvement suggestions for the identified problems. Researchers have argued that poorly expressed suggestions limit the understanding and implementation of the improvements thereby reducing the value of the HE effort (Molich et al., 2007). The suggestions should clearly articulate how the problem should be fixed. Good practices can be used to demonstrate the potential impact of the improvement. The suggestions should include the expected positive effect of the improvement on UX and business / DS&P development goals and priorities (Molich et al., 2007).

o *Evaluators' subjective rating of the perceived UX level:* Literature supports that UX is heavily subjective (Bevan, 2009) and UX perception can be an estimator of the user satisfaction (Erdinc et al., 2015). Hence, UX perceptions of the evaluators can be valuable HUXE output. A reliable rating scale should be selected to collect perceived UX ratings among the evaluators. The most common rating scale for subjective studies of the kind is 5-point Likert scale. However, the studies show that the scales having more than five response alternatives exhibit better psychometric properties (Lewis 1993; Preston & Colman, 2000), and 10-point scales have higher respondent preference (Preston & Colman, 2000). Hence, the PED framework proposes using a 10-point scale ranging from "0-Very poor" to "10-Excellent". The rating item can be structured and worded according to the scope of the evaluation. Subjective tools such as System Usability Scale (SUS; Brooke, 1996), Computer System Usability Questionnaire (CSUQ; Lewis, 1995) or Usability Metric for User Experience (UMUX; Finstad, 2010) can be helpful sources for building the rating item. The rating scores given by individual evaluators can be aggregated to form the mean perceived UX score.

The evaluation outputs should be effectively communicated and agreed upon among the expert team in the Planning phase. A strong understanding of the problem definitions and outputs would contribute to consistency in the evaluation (Molich et al., 2013).

4.2 Evaluation phase

- **Perform evaluation**: The Planning should produce a detailed road map that will lead to an effective Evaluation. The experts should evaluate the DS&P within the planned scope in line with the selected/developed heuristic rule set. The evaluation should be made individually and experts should address each heuristic rule. If the HUXE is task based, the evaluators should perform the tasks step-by-step to detect usability problems that a typical user would encounter. Severity of each problem should be rated using the agreed-upon scale. Additionally, actions to fix the problem should be considered and improvement suggestions should be developed.
- **Subjective rating**: As UX perception can provide valuable insights, the PED requires each evaluator to rate the UX for DS&P using the scale selected in the Planning phase. As mentioned earlier, the rating can be done in different ways to fit the scope of the evaluation. Each evaluator can provide ratings for; i) overall UX

level for the DS&P, ii) UX level of the specific parts or tasks, iii) each heuristic rule. The ratings by each evaluator can be transformed into a UX perception score of the expert team.

4.2 Delivery phase

- **Combine outputs**: When the evaluation is completed, the outputs should be combined into an expert report. Certain commonality across the detected problems can be expected. The evaluators should collaborate to finalize the problem descriptions and they should agree upon the severity ratings as well as the most effective improvement suggestion for each problem. In addition, the mean perceived UX ratings should be computed. Various methods can be applied to aggregate the findings and display the outputs. For example, the problems can be categorized and presented based on severity level. The aim and scope of the HE effort, as well as the evaluation approach should drive the method to combine the outputs. While research oriented evaluations require a quantitative analysis, business oriented evaluations can concentrate on the problem definitions and improvement suggestions.
- **Select significant problems:** Particularly for business and system improvement oriented evaluations, it should be taken into account that resources are limited in the industry and acting on each problem incurs cost. Thus, the evaluators should carefully consider each problem on the basis of business/DS&P development goals and priorities, and select the problems that pose significant impact on user performance, satisfaction and preferences.
- **Communicate outputs:** The value of the HUXE depends on the effective communication of the outputs. Presenting evaluation results in a high volume report can weaken the perception of the significant problems thereby limiting the contribution of the HUXE to system improvement. Communication format should fit the business/DS&P development goals and priorities, as well as the audience. It is very important that problems and improvement suggestions should be articulated with utmost clarity (Molich et al., 2007). While findings of the research oriented evaluations should be reported in academic format, business oriented evaluations can be communicated in different ways (e.g. reports, face-to-face meetings).

5. Conclusions and future work

The UX evaluation methods should be improved and extended in line with the constant changes in DS&Ps and IT field. The current study provided an overview of the HE methodology for usability context and proposed a new conceptual framework for HUXE in modern digital settings. The PED framework provides a step-by-step road map to conduct effective and efficient expert evaluations. The proposed framework should be refined and validated through field studies. Thus, the current study should be accepted as preliminary and the future studies should apply the PED to different DS&Ps and assess the validity, reliability and applicability of this new framework.

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Biography

Oguzhan Erdinc is an Associate Professor of Industrial Engineering at Turkish Air Force Academy. His current teaching and research areas include; Human Factors and Ergonomics, Human-Computer Interaction, Usability, User Experience and Service Management. His has several papers appeared in International Journal of Industrial and Systems Engineering, International Journal of Productivity and Quality Management, International Journal of Human Computer Interaction, Safety Science, and WORK. In collaboration with respected researchers he adapted several data collection tools for ergonomics and usability studies.

Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Pessimistic Supply Chain Efficiency Evaluation

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Abstract

Supply chain efficiency evaluation is a strategic approach for organizations or businesses to have competitive edge in today's global market, where it is more a competition of supply chain rather than competition of products. Time to market, customer satisfaction, capital/ income of the supply chain are some of the key factors that show the efficiency of a supply chain, which determines the success of a product or organization. The exaggeration of the performance of a supply chain is a problem for management, when decisions and improvements strategies are made based on the results of the evaluation. This exaggeration often leads to wrong forecast and shortfall of improvement. In this study, a modified variable return to scale (VRS) model is employed to evaluate the efficiency of pharmaceutical companies in India from a pessimistic point of view. The pessimistic point of view is considered because the worst case scenario gives management room to prepare for such events. India's pharmaceutical industry is undergoing a shift in business model according to Mishra (2012) to comply with the product patent regime from 2005, this evaluation points out the weak efficient and highly inefficient DMUs (Decision Making Units), in this case twenty-nine pharmaceutical companies. A comparison is made between the efficiency of BCC (Banker Charnes and Cooper) model with the modified VRS model to highlight the DMUs that are exaggerated. In addition, the weight distribution of the ten inputs and outputs used are analyzed to suggest resource allocation for performance improvement of the inefficient DMUs.

Keyword:

DEA, Pessimistic Efficiency, Standard and Modified Variable Returns to Scale Models

1. Introduction

Globalization has led to the dependence on supply chain as a method for organizations to achieve its goal of profit maximization. Companies now rely on systematic design of their processes to have competitive edge. Supply and demand activities, manufacturing capacity, logistics and procurement, customer experience, outsourcing, inventory and other activities necessary for customer satisfaction, which are within the supply chain context contributes to that target. For a supply chain to be successful, cross functional integration and marketing are critical for its success (Lambert & Cooper, 2000). Appropriate utilization of resources and infrastructure is a fundamental aspect of supply chain management. The correct amount of resources allocated to the right product, at the right time are also important facets of a supply chain. Multinationals and local organizations rely on supply chain to show their quality of service. Any supply chain that is capable of balancing resources to achieve the target outcome is considered efficient. Any attempt to make a supply chain more efficient is dependent on multiple factors, however, identifying the correct amount of resources towards achieving the target is imperative and this is where efficiency analysis of the supply chain comes in. Fortunately, data envelopment analysis (DEA) provides a nonparametric technique that evaluates the efficiency of entities known as decision making units (DMUs) with multiple inputs and outputs. DEA was introduced (Charnes et al., 1978) by presenting the CCR model based on (Farrell, 1957). It was later modified by (Banker et al., 1984) in the BCC model. DEA has evolved to become one of the most salient techniques for performance measurement problems with multiple applications in finance, energy, airports, health etc due to its robustness.

There have been many researches in supply chain management that used DEA models such as CCR and BCC models. However, the models used in these researches exaggerate the efficiency values of the weak efficient and highly inefficient DMUs. This exaggeration is of serious consequence to management when decisions are made based on the efficiency scores. (Daneshvar et al., 2014) proposed a modified variable return to scale (VRS) model that identifies the weak efficient and highly inefficient DMUs by assigning their real efficiency scores, while maintaining the efficiency score of DMUs located at the strong part of the efficiency frontier.

In this study a numerical example of 29 pharmaceutical companies in India used by (Mishra, 2012) is evaluated using eight inputs and two outputs. The rest of the article is organized as follows: section 2 is based on supply chain efficiency and preliminary notes on DEA. Discussion and numerical example is made in section 3, and the paper is concluded in section 4. Simulation is performed with Performance Improvement DEA (PIM-DEA) software, the leading software for data envelopment analysis.

2. Supply Chain Efficiency and DEA

Management thinker Peter Drucker often says "you cannot manage what you cannot measure". This means that success is not guaranteed unless the performance is tracked and measured, and efficiency evaluation is an important method of success measurement. Efficiency evaluation of an organization can be made for different purposes which include, understanding customer requirements, identifying problems and planning improvement strategies amongst others. The primary aim of efficiency measurement is to evaluate, control and improve operations processes (Ghalayini & Noble, 1996). Supply Chain Management (SCM) involves coordinating the flow of information, goods, services and finance between the supply chain members (Ruamsook et al., 2007). There are two criteria used in SCM, namely the cost minimization criteria (Camm et al., 1997) and profit maximization criteria (Cohen & Lee, 1989). SCM has a controlling factor on the survival or failure of a business or organization (Theodore Farris & Hutchison, 2002). Poor performance of a supply chain can be attributed to either lack of measurement system or incorrect performance evaluation. The aspect of incorrect performance evaluation provides management with misleading solution and approaches towards performance improvement. Organizations and businesses need to apply a pessimistic (worst case scenario) approach when executing performance evaluation. This will create a safe margin for error when implementing improvement strategies.

A considerable amount of studies have been made on performance measurement of supply chain, and DEA-Technique have been utilized for some of them, (Liu et al., 2000) used DEA to compare suppliers for supplier selection: their selection of inputs and outputs was based on a manufacturing firm. They used a simplified DEA model to compare suppliers' performance before selection. (Wong & Wong, 2007) used DEA to measure internal supply chain performance. (Liang et al., 2006) developed several DEA based approaches for characterizing and measuring supply chain efficiency when intermediate measures are incorporated into the performance evaluation. (Shafiee et al., 2014) used DEA and Balanced scorecard approach to evaluate the Iranian food industry supply chain efficiency. (Tajbakhsh & Hassini, 2015) use DEA to evaluate the sustainability of supply chain networks. (Tavana et al., 2016) used a two-stage DEA model for measuring performance in three-level supply chains, in their analysis; they concluded that a chain is comprehensively efficient if and only if there is efficient relationship between supply chain members.

Conventional efficiency definition is as follows: ${}^{Output}\!/_{Input}$. This definition becomes t when there are multiple inputs and outputs like the case of supply chain. A substitute is using weighted cost approach, which is: $\frac{Weighted\ sum\ of\ Outputs}{Weighted\ sum\ of\ Inputs}$. The problem with this method is that, it assumes that all the weights are uniform.

DEA calculates the relative efficiencies of DMUs with multiple inputs and outputs. The efficiency of each DMU is measured in comparison to other DMUs. Generally the efficiency score of a DMU is defined as the weighted sum of outputs divided by the weighted sum of inputs, while the weights are assigned. The weights are computed by giving the highest possible score to a DMU while maintaining the efficiency scores of all DMUs less than or equal to one under the same set of weights. The BCC model frontier of DEA has a concave characteristic with regards to its production possibility set (PPS). The PPS of the BCC model which is denoted by T_c has the following properties:

(P1) All observed input and output (X_j, Y_j) included in T_C $(j = 1, \ldots, n)$

(P2) If the inputs and outputs (x_j, y_j) belongs to T_C , then the convex combination of these data $(\sum_{j=1}^{n} \lambda_j X_j, \sum_{j=1}^{n} \lambda_j Y_j)$, $\sum_{j=1}^{n} \lambda_j = 1$ $\lambda_j \geq 0$ j=1, 2,…, n also belongs to T_C

(P3) For all inputs and outputs (X, Y) included in T_C any combination of input and output $(\bar{X}, \bar{Y})$ with $\bar{X} \geq X$ and $\bar{Y} \leq Y$ belongs to T_C.

(P4) All linear combination of inputs and outputs in T_C are included in T_C

(Banker et al., 1984) proof that by using the mentioned properties of T_C defined by:

$$T_C = \{(X, Y) | X \geq \sum_{j=1}^{n} \lambda_j X_j , Y \leq \sum_{j=1}^{n} \lambda_j Y_j , \sum_{j=1}^{n} \lambda_j = 1 \ \lambda_j \geq 0, \forall j\} \tag{1}$$

For evaluating the efficiency of DMU_k which belongs to PPS (T_C) in output orientation, it should find the maximum value of θ (efficiency score) in a manner that $(x_k, \theta y_k) \in T_c$. The linear program derived from these properties in output orientation form is as follows:

$$\begin{aligned} & Max\ \theta \\ & subject\ to \\ & \sum_{j=1}^{n} \lambda_j X_j \leq X_k \\ & -\sum_{j=1}^{n} \lambda_j Y_j + \theta Y_k \leq 0 \\ & \sum_{j=1}^{n} \lambda_j = 1 \\ & \lambda_j \geq 0 \qquad\qquad j = 1, \ldots, n \end{aligned} \tag{2}$$

Model (3) illustrates the dual of model (2) as follows:

$$\begin{aligned} & Min \sum_{i=1}^{m} v_i x_{ik} + v_0 \\ & subject\ to \\ & \sum_{r=1}^{t} u_r y_{rk} = 1 \\ & \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{t} u_r y_{rj} + v_0 \geq 0 \qquad j = 1, \ldots n \\ & v_i \geq 0 \qquad i = 1, \ldots, m \\ & u_r \geq 0 \qquad r = 1, \ldots, t \\ & v_0\ free \end{aligned} \tag{3}$$

Model (3) is the BCC Model of (Banker et al., 1984). The modified VRS model used in this study was introduced by (Daneshvar et al., 2014), it is a modification on the “BCC model” model (3). The modification examines the weak part of the efficiency frontier were the weak efficient DMUs are located and DMUs that get their efficiency value when compared to the weak part of the frontier, by using facet analysis of (Banker & Thrall, 1992) as shown in model (4) on the DMUs evaluated by model (3), the modification is made by placing a upper bound "η" from equation (5) on the free variables v_0 of the BCC model in model (3). The modified VRS model is shown in model (6).

Where u_r is the weight of output *r*, v_i is the weight of input *i* , y_{rj} is the amount of *r* output for DMU *j*, x_{ij} is the amount of *i* input for DMU *j*, *t* is the amount of output, *m* is the amount of input. *n* is the number of DMUs, ε^* is the efficiency score from the modified VRS model (output orientation). A DMU *k* is deemed efficient if the objective function is equal to one and inefficient if less than one.

$$
\begin{aligned}
& v_0^+ = Max\ v_0 \\
& subject\ to \\
& \sum_{i=1}^{m} v_i x_{kj} + v_o = 1 \\
& \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{t} u_r y_{rj} + v_0 \ge 0 \qquad j = 1, \ldots, n \\
& \sum_{r=1}^{t} u_r y_{kj} = 1 \\
& u_r \ge 0 \qquad for\ r = 1, \ldots, t \\
& v_i \ge 0 \qquad for\ i = 1, \ldots, m \\
& v_0 \quad free
\end{aligned} \tag{4}
$$

$$
\eta = Min\ \left\{ v_0^+ \mid v_0^+ \ne -\infty\ for\ \ efficient\ \ DMUs \right\} \tag{5}
$$

$$
\begin{aligned}
& \varepsilon^* = Max \sum_{i=1}^{m} v_i x_{ik} + v_o \\
& subject\ to \\
& \sum_{r=1}^{t} u_r y_{rj} = 1 \\
& \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{t} u_r y_{rj} + v_0 \ge 0 \qquad j = 1, \ldots, n \\
& u_r \ge 0 \qquad for\ r = 1, \ldots, t \\
& v_i \ge 0 \qquad for\ i = 1, \ldots, m \\
& v_0 \ge \eta
\end{aligned} \tag{6}
$$

2.1 A case India's Pharmaceutical Industry

To comply with the Trade Related Intellectual Property rights agency (TRIPS) in India. Pharmaceutical companies have been undergoing a major shift in their business model to comply to the product patent regime of 2005. This was based on the presumption that protecting an innovator's interest would encourage more innovations.

Effective marketing strategy, short time to market and strategic sourcing alliances are ways that pharmaceutical firms in developed countries use to recuperate research and development (R&D) investments and optimize sales from limited patent periods (Mishra, 2012). India is an attractive destination for pharmaceutical companies to outsource their production. According to (www.ciionline.org), the cost of setting up a plant is 40% lower and the cost of producing a bulk drug is 60% lesser than that of other developed counties. In addition, low cost of manpower, processing capabilities and protection for their patented products through intellectual property production laws contribute to that effect. Until recently pharmaceutical companies of developed countries do not venture into outsourcing to India due to their reverse engineering practices. India's pharmaceutical industry is the fourth largest in the world after US, Japan and Germany. Precedently, most of the drugs produced in India were either off patented generics or reverse engineered, which is allowed so long as the method of production is different. The change from process patenting to product patenting of the patent regime implemented in 1995 compelled some of the larger and mid-sized drug companies to invest in R&D of new drug development. They also began exploring possible contract manufacturing of patented and off-patented drugs.

Outsourcing R&D and production to lower cost destinations like India became a logical option due to globalization, production cost and R&D expenditures. This was also favored by the trade liberalization of 1991, thereby minimizing various licensing required for import, export tariffs in India's pharmaceutical industry. This created avenues for joint ventures, partnership, R&D collaborations between domestic companies and multinationals. Foreign companies began considering India as a destination for low-cost manufacturing facilities which acts mainly as their sourcing centers and international operation centers.

In this study we considered the 29 Indian pharmaceutical companies used by (Mishra, 2012) to highlight our pessimistic efficiency evaluation model.

3. Discussion with a Numerical Example

Table 1 gives the description of the list of inputs and outputs used in the analysis. Table 2 shows the DMUs labelled P01 to P29 representing the pharmaceutical companies in India with eight inputs and two outputs as classified in Table 1. Table 3 shows the comparison between the efficiency of the BCC model and modified VRS model. The upper bound for "η" in the modified VRS model is (+0.44) using model (4) and equation (5) on all the efficient DMUs.

Table 1: Classification of Inputs/Output

Inputs	Outputs
X1: Internal Manufacturing Capacity (IMC) X2: Supply chain cost (SC)[Rs. In lakhs] X3: Working Capital (WC) [Rs. In lakhs] X4: Invested Capital (IC) [Rs. In lakhs] X5: Number of Employees (NE) X6: Wages to Workers (WW) [Rs. In lakhs] X7: Materials Consumed (MC) [Rs. In lakhs] X8: Fuels Consumed (FC) [Rs. In lakhs]	Y1: Net Value Added due to supply chain (NVA) [Rs. In lakhs] Y2: Net Income (NI) [Rs. In lakhs]

Table 2: Input/Output data

DMUs	x1	x2	x3	x4	x5	x6	x7	x8	y1	y2
P01	682	13370	14629	34049	80384	3046	1819	31941	15695	13289
P02	800	14602	16654	36425	85559	7850	39386	49408	18557	21653
P03	866	15791	19878	39528	85603	3798	2948	44231	24808	21653
P04	918	17485	22865	45312	103468	4356	3286	52416	27041	23753
P05	1043.54	25926.44	29277.7	62355.6	113889.1	6347.548	4474.414	67180.3	31588.02	27000.81
P06	1219.458	32886.27	36425.09	78678.88	126789.8	8064.555	6118.149	87730.82	33183.87	27273.99
P07	1463.03	48621.55	48412.9	109618.9	145643.5	10969.61	9678.177	120682.3	37143.91	29137.97
P08	1253.418	43599.54	42111.49	98570.89	125700.5	10177.62	9073.948	110564.1	47580.52	39171.38
P09	1187	44194	42639	101515	120396	10867	8619	117083	63307	53079
P10	1591.744	65135.01	63004.67	150729.5	156572.4	15787.82	12437.64	175519.6	57120.2	44540.19
P11	1294.544	55761.96	57862.96	127493.7	126839.4	12773.04	10194.86	148486	76270.44	51667.06
P12	1374	62117	46735	130898	120174	15160	1921	11938	6600.07	13474
P13	1497	73434	55204	155980	134779	18734	1985	15437	10679	17609
P14	1554	87577	72869	201616	135384	20356	15752	246382	101463	80613
P15	1105.987	104327	54167.57	168880.4	101967.3	9311.04	13332.43	230342.2	34346.54	16549.99
P16	1007.3	106240.7	41592.15	155570.3	83280.97	7094.861	13836.86	155600.3	51980.68	31798.51
P17	1261.485	116301.6	62121.56	179343.7	101551.6	9170.063	16646.79	162168.9	61581.27	35849.97
P18	1496.279	180235	120651.4	292782.1	122377.3	16622.72	25245.43	325385.5	89444.06	44670.56
P19	1968.829	312556.3	138548.3	443374.2	132094	18483.44	34181.46	380080.9	103531.9	54816.81
P20	2845.766	440808.4	243977.3	645401.1	168405.8	25547.08	49308.44	454865.9	154441.8	50278.68
P21	3293.549	594489.2	228029.7	809059.5	171165	27979.91	55783.36	524551.4	175744.4	75499.46
P22	3855	982507	206070	1186858	132180	24320	51959	690302	257688	176840
P23	4046	719461	255442	937341	134861	136618	9292	63597	57905	65168
P24	587	230394.9	177104	342808.2	47972.94	17528.92	18909.9	496375.5	235769	26661
P25	608	398729.6	170768.6	574175.9	44295.87	17207.48	22063.02	615935	125600	49463
P26	640	228821	150160	354173	36194	16142	19060	546393	107364	54759
P27	642	303888.9	89306	431703.2	39541	16541.75	22097	629821.8	90702	22399
P28	621	591	285636	116035	25592	1536	777	4116	616915	598
P29	12656	3303003	600909	4055974	472330	140109	1028465	1716212	1062762	868909

Table 3: BCC and Modified VRS Efficiency

DMUs	BCC	Modified VRS	DMUs	BCC	Modified VRS
P01	100	100	P16	97.78	94.08
P02	100	100	P17	71.24	71.24
P03	100	100	P18	58.82	58.44
P04	100	100	P19	56.89	56.49
P05	89.07	89.07	P20	46.28	44.82
P06	69.37	69.37	P21	57.28	55.75
P07	54.19	54.14	P22	100	100
P08	78.05	78.02	P23	100	100
P09	100	100	P24	100	100
P10	67.9	67.86	P25	100	100
P11	88.66	88.66	P26	100	100
P12	100	100	P27	100	100
P13	100	100	P28	100	100
P14	100	100	P29	100	100
P15	38.15	36.75			

Table 4: Weights of Inputs/Outputs for Modified VRS

DMUs	x1	x2	x3	x4	x5	x6	x7	x8	y1	y2
P01	0	0	8.55	0	39.19	0	8.08	15.76	0	65.39
P02	0	0	36.31	0	0	0	3.97	0	0	40.13
P03	0	165.03	0	0	0.31	0	1.68	0	0	40.13
P04	0	151.87	0	0	0	0	1.26	0	0	36.58
P05	0	0.81	0	0	0	0.15	207.05	0	0.59	31.61
P06	0	0.8	0	0	0	0.15	204.83	0	0.59	31.27
P07	0	7.94	0	0	0	19.68	2.94	0	0.62	29.17
P08	0	7.43	0	0	0	14.64	0	0	0	22.18
P09	0	4.31	0	0	0	0	0	11.93	0	16.37
P10	0	14.75	0	0	0	0	0	5.67	1.04	18.41
P11	0	5.52	0	0	0	6.18	5.77	0	0.82	15.83
P12	0	0	0.03	0	0	7.01	0	62.56	0	64.49
P13	0	2.28	0	0	0	0	319.63	0	0.93	48.88
P14	0	1.23	0	0	0	0	6.31	3.76	0.58	10.18
P15	10.82	0	13.4	0	9.82	0	28	0	9.5	36.38
P16	0	0	10.72	0	13.11	0	5.56	0	0	27.33
P17	0	7.98	0.42	0	4.65	8.57	3.15	0	0	24.24
P18	6.81	1.95	0	0	0	4.99	6.3	0	0.75	18.22
P19	5.57	1.59	0	0	0	4.08	5.15	0	0.61	14.9
P20	0	4.69	0	0	0	0	11.52	0	1.82	12.72
P21	0	3.34	0	0	0	0	8.2	0	1.29	9.05
P22	0	1.74	0	0	1.04	0	2.34	0	0.22	4.65
P23	0	2.14	0	0	0	0	0	11.07	0	13.33
P24	33.3	0	3.87	0	0	0	0	0	3.07	10.41
P25	42.35	0	0	0	0	0	0	0	0	17.57
P26	0	12.74	0	0	4.84	0	0	0	0	15.87
P27	0	0.32	9.34	0	10.46	0	15.58	0	5.82	19.53
P28	0	0	0	0	0	0	3.31	0	1.72	0
P29	0	0	0	0	0	0	0.89	0	0.19	0.53
Average	3.408621	13.74	2.849655	0	2.876552	2.256897	29.36276	3.818966	1.04	23.97759

The modified VRS model which is the emphasized model in this study highlights the DMUs that are worse than they appear as identified by the BCC model. As can be seen in Table 3, DMUs P07, P08, P10, P15, P16, P18, P19, P20 and P21 are all more inefficient than evaluated by the BCC model. Hence, the pharmaceutical companies identified by these DMUs need to take special measures to improve their efficiency. The pessimistic nature of the Modified VRS model suggests that more resources should be allocated to the inefficient DMUs to improve their efficiency.

The weights distribution in Table 4 shows that the omission of X4 (Invested capital) will not affect the efficiency scores significantly. Contrary to X4, X7 (Materials consumed) and Y2 (Net Income) contributes the most to the efficiency of the industry from their average weight distribution. This is logical because, the pharmaceutical industry in India is a quantitative (bulk production) industry. Therefore the inefficient companies need to focus on producing more products, there by consuming more materials which directly increases the Net value added to the supply chain Y1 and Net income Y2.

4. Conclusion

This study utilized the Modified VRS model to evaluate the efficiency of supply chain from a pessimistic perspective. The comparison of the efficiency score for the Modified VRS model and the BCC model shows the DMUs that are exaggerated. The findings of this study are especially significant to the management of the pharmaceutical companies because, the exaggeration of performance (efficiency) often leads to shortfall of improvement when the improvement strategies are based on the optimistic evaluation. Moreover this study suggests the use of Modified VRS model to assess the performance evaluation of supply chain.

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Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Analysis and Validation of Several Emission Models for Automobiles Using Real-Time Data

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Abstract

Despite the number and variety of emission models proposed in the literature, studies on their validation using real-life data is limited. This paper reviews and numerically compares six such models against data collected in real-time from a passenger vehicle on a route, using a mobile phone application. Our findings reveal that, whilst the results obtained by the models vary depending on the value of the inputs such as speed, some of the models tested here are able to provide CO_2 emission estimations with a mean absolute error value of around 3.97.

Keywords

CO_2 emission, instantaneous models, Fuel Consumption, Passenger car

1. Introduction

Over one third of global energy usage is due to transportation (Ahn & Rakha, 2008; (Rakha, Ahn, Moran, Saerens, & Bulck, 2011), the majority of which is obtained through petroleum products. Consumption of fuel by vehicle engines results in greenhouse gas (GHG) emissions, the most prominent of which is CO_2, all of which have detrimental effects on the environment. The second largest source of CO_2 emissions is the combustion of gasoline and diesel in vehicles used in transportation ("Carbon Dioxide Emissions | Climate Change | US EPA", 2016). To reduce environmental externalities, it is imperative that fuel efficiency of vehicles is improved. To this end, whilst renewable fuel sources and alternative fuel vehicles might be a solution in the long-term, reducing emissions and fuel consumption of vehicles operating under existing technologies should be the goal in the short to medium term.

The amount of CO_2 emissions from a vehicle is proportional to the amount of fuel consumed by the engine. Fuel efficiency depends on the driving mode, which in turn is dependent on several factors. There are many different ways to estimate emissions using the information on fuel consumption. However, the choice of the nature of emission functions becomes crucial for when accurate estimates are needed in planning for transportation, be it at operational, tactical or strategic levels. The literature is relatively rich in describing models to estimate fuel consumption of vehicles, but numerical validation results are limited, are described only for some of these models, and in isolation. Further empirical studies using real data are needed not only to gauge the quality of the estimations suggested by such models, but also to be able to provide comparison results across the various models.

This is precisely the aim of the present paper. In particular, the main contribution of this study is to test the performance of six existing vehicle emission models from the literature against real-time data that is collected from a passenger car using existing on-board diagnostics (OBD2), a Bluetooth interface and a smartphone. Using the results, we provide a numerical comparison of the six models.

The rest of the paper is structured as follows. In Section 2, we provide a brief overview of the relevant literature. Section 3 describes the emission models tested in the paper, followed by a description of the experimental set-up and process of data collection in Section 4. Numerical results are presented in Section 5 and conclusions are given in Section 6.

2. Review of the Existing Work

Relevant work on the topic dates back to the late 80s, one of which is by Biggs and Akçelik (Biggs & Akcelik, 1987) who compared central districts with urban and non-urban areas by using different size vehicles. The accuracy in prediction of fuel consumption rate against CO_2 emissions has been validated and implemented in many national institutions (Wang, Fu, Zhou, & Li, 2008). A study by Wang et al. (Wang, Fu, Zhou, & Li, 2008) found that driving patterns might play an important role on fuel consumption. They show that fuel consumption rates increase significantly when the vehicles accelerate but change little during deceleration. Oh et al. (Oh, Park, Lee, Eom, & Park, 2014) presented a comparison of 10 different passenger vehicles for seven driving modes based on simulated data. They show that the gross weight and the speed of the vehicle have significant effects on fuel consumption, whereas those of rolling resistance, frontal area and air drag are negligible. Further research on fuel consumption models has also shown that the vehicle speed, load, and road gradient have a significant effect on the fuel consumption (Demir, Bektaş, & Laporte, 2011). Chaim et al. (Ben-Chaim, Shmerling, & Kuperman, 2013) looked at vehicle fuel consumption under two different operating modes, namely cruising at constant speed and acceleration. They showed that the fuel consumption depended on instantaneous engine efficiency under each mode. They (Oduro et al., 2013) conducted experiments to model the relationship between the tire pressure and fuel consumption, and showed that by using a recommended tire pressure, fuel consumption can be reduced by 17.6%, which lowers emissions by similar amounts. Da Rocha et al. (Vieira da Rocha et al., 2013) studied the relevance of microscopic traffic models for estimating the impact of traffic strategies on fuel consumption. Smit et al. (Smit, Brown, & Chan, 2008)] used the three average speed models, namely COPERT III, MOBILE 6, EMFAC 2000 to estimate emissions and fuel consumption from road traffic and include the effects of congestion. The authors suggested that a congestion algorithm might be incorporated in to the model to improve current average speed models. They also evaluated the effect various vehicle parameters, local traffic conditions and driving behavior on vehicle emissions and fuel consumption for conventional vehicles.

A study by Van Mierlo et al. (Van Mierlo, Maggetto, Van de Burgwal, & Gense, 2004) found that driving style might play an important role on fuel consumption and emissions. Li and Sun (Li & Sun, 2014) proposed a model of vehicle-pedestrian interactions and the effect on traffic fuel economy and emissions. On-ramp can enhance each vehicle's fuel consumption on the main road and that the increments are related to the traffic state of the main road and the inflow of the on-ramp (Tang, Li, Yang, & Shang, 2015).Ho et al Emissions and fuel consumption estimation models play a key role in the evaluation of the environmental impacts of intelligent transportation systems strategies (Ho, Wong, & Chang, 2014)formulated a representative driving cycle, with consideration of distance, road type and duration, for passenger cars in Singapore in order to reduce the emissions and fuel consumption. Euro 4 petrol car driven on four typical urban routes in Hong Kong (Tsang, Hung, & Cheung, 2011),Euro III and IV buses fueled on diesel and compressed natural gas in Beijing (Wang et al., 2011),gasoline passenger cars in Bangkok (NUTRAMON & SUPACHART, 2009)were analyzed to obtain the effects of on-road emissions and fuel consumption.

There exists research looking at the effect of street characteristics, driver category and car performance on urban driving patterns (Brundell-Freij & Ericsson, 2005), high altitude on fuel consumption of a gasoline passenger car (Zervas, 2011), driving behaviors, road slope and vehicle load factor on bus fuel consumption and air pollutant emissions (Carrese, Gemma, & La Spada, 2013),route choice decisions on vehicle energy consumption and emissions (Ahn & Rakha, 2008), and the effect of a driver support tool, the acceleration advisor, on fuel consumption and emission (Larsson & Ericsson, 2009). In (Saboohi & Farzaneh, 2009), controlling speed and selecting and appropriate gear ratio with respect to different engine loads were considered for implementation of optimal driving strategy to minimize the fuel consumption. A study by Aksoy et al. (Aksoy, Küçükoğlu, Ene, & Öztürk, 2014) showed that the fuel consumption and CO_2 emission amount has direct correlation with the type of vehicle chosen and the distance traveled.

At the local and regional levels, a significant portion of freight transportation is carried out by trucks, which emit a large amount of pollutants. In (Demir, Bektaş, & Laporte, 2014), a review of recent research on green road freight transportation is presented. Walnum and Simonsen (Walnum & Simonsen, 2015)studied the known and potential factors for reducing fuel consumption in heavy-duty vehicles, and suggest that modifying driving behavior can potentially lower fuel consumption. Other studies have looked at on-road emissions for a heavy-duty public transit buses using different fuel systems in Beijing using portable emission measurement systems (Zhang et al., 2014)and for light-duty passenger vehicles in three cities in China with a particular focus on fuel consumption (Zhang et al., 2014).

3. Emission Models

This section presents the six emission models tested in this paper. All models chosen here are instantaneous, i.e., they provide a second-by-second estimation of fuel consumption of a vehicle. We convert fuel consumption units from liter per kilometer to gram of CO_2 per km (Diesel) by 1l/km=2650 g/km. Besides, the notation common to all the models are given as follows:

v is the speed of the vehicle (meter/second),

T is the total journey duration (second),

M is the total weight of the vehicle (kilogram),

a is the instantaneous acceleration (meter/second2),

ω is the road gradient (%),

g is the gravitational constant (meter/second2), which is approximately equal to 9.81,

ρ is the air density (in kilogram/meter3), typically between 1.1455 and 1.4224,

A is the frontal surface area (in meter2), typically between 2.0 and 5.6),

C_d is the coefficient of aerodynamic drag, typically between 0.25 and 0.9,

C_r is the coefficient of rolling resistance, typically between 0.006 and 0.015.

We now present each of the six models in more detail:

3.1 An instantaneous fuel consumption model (IFCM)

IFCM is described by Bowyer et al., (1985) as an energy-based model, according to which the instantaneous fuel consumption *f*(*t*) of a vehicle of weight *M* moving at speed v can be calculated (in milliliter/second) as

$$f(t) = \begin{cases} \alpha + \beta_1 R(t) v + (\beta_2 M a^2 v/1000) for R_t > 0 \\ \alpha for R_t \leq 0 \end{cases}, \quad (1)$$

where $R(t)$ is the total tractive force (kilo-newton) calculated as $R(t) = b_1 + b_2 v^2 + Ma/1000 + gM\omega/100000$, in which α is the constant idle fuel rate (in milliliter/second, typically between 0.37 and 0.56), β_1 is the fuel consumption per unit of energy (in milliliter/kilojoules, typically between 0.09 and 0.08), β_2 is the fuel consumption per unit of energy-acceleration (in milliliter/(kilojoules × meter/second^2), typically between 0.03 and 0.02), b_1 is the rolling drag force (in kilo newton, typically between 0.1 and 0.7), and b_2 is the rolling aerodynamic force (in kilo newton/ (meter/second^2,), typically between 0.00003 and 0.0015). With IFCM model, the total amount *F*(*T*) of fuel consumption (milliliter) for a trip of duration *T*, with all other parameters such as speed remaining constant, can be calculated as

$$F(T) = \int_0^T f(t)\mathrm{d}t. \quad (2)$$

The values of the parameters presented above are from Bowyer et al. and Akçelik, and Besley , (1990 and 2003).

3.2 A four-mode element al fuel consumption model (FMEFCM)

FMEFCM is another model described by Bowyer et al. [36] and can be regarded as a more detailed version of IFCM. For this reason, it uses the same set of parameters as with the IFCM, but includes additional ones reflecting initial and final speeds. This model explicitly takes into consideration the amount of fuel consumed in four modes (or phases) of driving, namely acceleration (*a*), deceleration (*b*), cruise (*c*) and idle (*d*), denoted by $F_a(t_a)$, $F_d(t_d)$, $F_c(t_c)$ and $F_i(t_i)$, respectively, where t_a, t_d, t_c and t_i are the times spent under each phase. The explicit calculations for each of the four modes are given below.

a. Acceleration mode: The fuel consumption during the acceleration phase is calculated as

$$F_a(t_a) = max\{\alpha t_a + \left(\Gamma + k_1 B\left(v_i^2 + v_f^2\right) + \beta_1 M E_k + k_2 \beta_2 M E_k^2 + 0.0981 \beta_1 M \omega\right) x_a, \alpha t_a\} \quad (3)$$

where E_k shows the change in kinetic energy per unit distance during acceleration and is calculated as $E_k = 0.3858\,(10)^{-4}(v_f^2 - v_i^2)\,/x_a$ and where v_f is final speed and v_i is initial speed of vehicle. In addition, $k_1 =$

$0.616 + 0.000544v_f - 0.0171\sqrt{v_i})$, $k_2 = 1{,}376 + 0.00205v_f - 0.00538v_i$, Γ is a parameter (in milliliter/kilometer) typically between 21 and 100, and B is another parameter (in (milliliter/kilometer)/$(\text{kilometer/hour})^2$ typically taking a value between 0.0055 and 0.018. If the travel distance x_a and the travel time t_a are not known, they can be estimated using $x_a = m_a\,(v_f + v_i)t_a\,/3600$, where $m_a = 0.467 + 0.00200v_f - 0.00210v_i$ and $t_a = (v_f - v_i)/\,(2.08 + 0{,}127\sqrt{v_f - v_i} - 0.0182v_i)$.

b. Deceleration mode: The fuel consumption in this case is

$$F_d(t_d) = \max\{\alpha t_d + \left(k_x\Gamma + k_y k_1 B\left(v_i^2 + v_f^2\right) + k_a\beta_1 M E_k + k_x\beta_1 M E_k^2 + 0.0981\beta_1 M\omega\right)x_d, \alpha t_d\} \quad (4)$$

where $k_x = 0.046 + 100/M + 0.00421\,v_i - 0.00260v_f + 0.544\omega$, $k_y = k_x^{0,75}$, $k_a = k_x^{3,81}(2 - k_x^{3,81})$ and $k_1 = 0.621 + 0.000777v_i - 0.0189\sqrt{v_f}$.

c. Cruise mode ($\boldsymbol{F_c(t_c)}$): The fuel consumption in this mode is given by

$$F_c(t_c) = \max\{f_i/v_c + \Gamma + Bv_c^2 + k_{E1}\beta_1 M E_{k+} + k_{E2}\beta_2 M E_k^2 + 0{,}0981 k_G\beta_1 M\omega,\ f_i/v_c\}x_c, \quad (5)$$

where f_i denotes the idle fuel rate (in milliliter/hour), v_c is the average cruise speed (kilometer/hour), x_c stands for the travel distance (kilometer) and $E_{k+} = \max\{0.258 - 0{,}0018v_c,\ 0.10\}$ and the other calibration parameters are $k_{E1} = \max\{12.5/V_c - 0{,}000013v_c^2,\ 0.63\}$, $k_{E2} = 3.17$ and $k_G = 1 - 2.1E_{k+}$ for $\omega < 0$ and $k_G = 1 - 0.3E_{k+}$ for $\omega > 0$.

d. Idle mode: The amount of fuel consumption when the vehicle is idle is calculated as

$$\mathrm{F_i(t_i)} = \alpha t_i \quad (6)$$

where t_i is the idle time spent (seconds), and α is the idle fuel rate (milliliter/second).

With FMEFCM, the total fuel consumption (milliliter) using the all four modes can be calculated as;

$$F(t_a, t_d, t_c, t_i) = \int_0^{t_a} F_a(t_a)\,d_t + \int_0^{t_d} F_d(t_d)\,d_t + \int_0^{t_c} F_c(t_c)d_t + \int_0^{t_i} F_i(t_i)\,\mathrm{d}t. \quad (7)$$

3.3 Physical emission rate estimator (PERE) model

PERE was first presented by Nam and Giannelli (Nam and Giannelli, 2005)to measure vehicle emissions, according to which the fuel consumption (kilogram/second) is calculated as:

$$f_{pr}(t) = \xi\{kNV + (P_b(v)/\eta_t + P_{acc})/\eta\}/41.7 \quad (8)$$

where ξ is the fuel air equivalence ratio (typically 1), k is the engine friction (typically between 0.15 and 0.25), N is the engine speed (typically between 15 and 80 RPS), V is the engine displacement volume (typically between 1 and 7), η_t is a transmission and final drive efficiency (typically between 0.4 and 0.45), P_{acc} is the power draw of accessories (typically 0).
The power demand (watts) can be calculated as

$$P_b(v) = C_r v + Bv^2 + C_d v^3 + Mv(a + g\omega) \quad (9)$$

where A, B, C are model specific constants calculated as $A = C_{R0}Mg,\ B = 0.0, C = C_d A_r\rho/2 + C_{R2}Mg,$ and C_{R0} and C_{R2} are the zero and second order in speed rolling resistance force terms, respectively. Using PERE, the total fuel consumption (kilogram) over a trip of duration T is calculated as

$$F_{pr}(T) = \int_0^T f_{pr}(t)\mathrm{d}t. \quad (10)$$

3.4 A comprehensive modal emission model (CMEM)

CMEM was formulated by Scora and Barth (Scora and Barth, 2016) and Barth and Boriboonsomsin (Barth and Boriboonsomsin, 2008) for heavy-goods vehicles, and consists of three modules relevant to engine power, engine speed and fuel rate, respectively. We explain these modules further in the below.
The engine power module: The total tractive power is the base of the power demand function $P_{tract}(t)$ (kilowatt) calculated as follows.

$$P_{tract}(t) = (Ma + Mg \sin\omega(\theta) + 0.5\, C_d \rho A v^2 + MgC_r \cos\omega(\theta))\, v/1000\ . \tag{11}$$

The transformation from tractive power to engine power is shown by the expression below,

$$P(t) = P_{tract}(t)/\eta_{tf} + P_{acc} \quad , \tag{12}$$

where *P(t)* is the second-by-second engine power output (kilowatt), and η_{tf} is the vehicle drive train efficiency.
The engine speed module: Engine speed is related to vehicle speed in the following way,

$$N(v) = S\left(\frac{R(L)}{R(L_g)}\right) v_i \quad , \tag{13}$$

where *N(v)* is the engine speed (in rpm), *S* is the engine-speed/vehicle-speed ratio in top gear L_g, *R(L)* is the gear ratio in gear $L = 1,\dots, L_g$, and η is the efficiency parameter for engines.
The fuel rate module: The fuel rate (gram/second) is formulated as

$$F_{cm}(t) = \xi\, (kN(v)V + P(t)/\eta)\ /41.7\ . \tag{14}$$

According to CMEM, the total fuel consumption (in grams) by a vehicle for a trip of duration *T* is given by:

$$F_{cm}(T) = \int_0^T f_{cm}(t)dt. \tag{15}$$

3.5 A running speed fuel consumption model (RSFCM)

The running speed fuel consumption model is derived from FMEFCM and was presented by Bowyer et al., (1985). The model evaluates fuel consumption individually during driving modes when a vehicle is running idle. Within this model, all driving modes are accounted for simultaneously within a single function. The RSFCM estimates the total fuel consumption $F\ (t_i, t_s)$ of a vehicle traveling over a total distance of x_s at an average running speed v_r (kilometer/hour) as follows:

$$F\ (t_i,\ t_s) = \max\{\alpha t_i + (f_i/v_r + A + Bv_r^2 +\ k_{E1}\beta_1 ME_{k+} +\ k_{E2}\beta_2 ME_k^2 +\ 0{,}0981 k_G \beta_1 M\omega) x_s,\ \alpha t_s\} \tag{16}$$

where is the total fuel consumption (milliliter), respectively. The average speed is calculated as $v_r = 3600x_s/(t_s - t_i)$ with t_s and t_i representing the travel and idle times, respectively. In addition, $E_{k+} = \max\{0.35 - 0.0025\mathrm{v_r}, 0.15\}$, $k_{E1} = \max\{0.675 - 1.22/v_r - 0.5\ \}$ and $k_{E2} = 2.78 + 0.0178v_r$. The data requirements of the RSFCM are much less than FMEFCM, but the model provides less accurate fuel consumption estimations.

3.6 Vehicle specific power model

The vehicle specific power model (VSPM) proposed by Jimenez-Palacios (Jimenez-Palacios, 1998) is a microscopic model to estimate vehicle fuel consumption and emission rates on a second-by-second basis. The vehicle specific power is dependent on the load of a vehicle and is defined as the power per unit mass to overcome road gradient, rolling and aerodynamic resistance, and acceleration, for which factors such as instantaneous speed, acceleration and road gradient are used. The vehicle specific power at a given point in time *t*, denoted by *VSP*(*t*) and expressed in kilowatt/ton, can be calculated using an equation given by United States Environmental Protection Agency and is given as below.

$$VSP(t) = v(a(1 + \epsilon_m) + g\ sin(arctan(\ \omega)\ + gC_r) + 0.5\ C_d \rho A v^3\ /M \tag{17}$$

In (17), ϵ_m is the mass factor (typically between 0.1 and 0.2).

The power demand $P_{vsp}(t)$ (kilowatt) calculated as follows.

$$P_{vsp}(t) = \mathrm{VSP(t)\ M/1000} \tag{18}$$

The fuel rate (gram/second) is formulated as

$$f_{vsp}(t) = \xi\{kNV + (P_{vsp}(t)/\eta_t + P_{acc})/\eta\}/41.7 \tag{19}$$

P_{acc} is the power draw of accessories (typically 0).

Total fuel consumption (in grams) by a vehicle for a trip of duration T is given by:

$$F_{vsp}(T) = \int_0^T f_{vsp}(t)\mathrm{d}t. \tag{20}$$

VSPM is also used as a base model to measure power demand in different emission models.

4. Experimental Set-up and Data Collection

In order to numerically test and compare the emission models above, data was collected in real-time from a single passenger vehicle, namely a 2013 Toyota Corolla 1.4D-4D multimode running on a diesel engine, weighing 1425 kg, with 2.09 m^2 frontal area. The aerodynamic drag coefficient and the engine displacement values are 0.29 and 1396 ml, respectively. The vehicle was driven over six different levels of fixed speeds, ranging from 45 km/h to 120 km/h in increments of 15 km/h.

The route is located in Istanbul, Turkey, and is shown on the map that appear in Figure 1, along with its elevation graph. The map shows the beginning and end of the route with the letters A and B.

The route is part of what is known as the Basin Ekspres road, and is of 3.5 km length. The latitude and longitude coordinates of the start and end points of the route are (41.0094, 28.8128) and (41.01717, 28.81229), respectively.

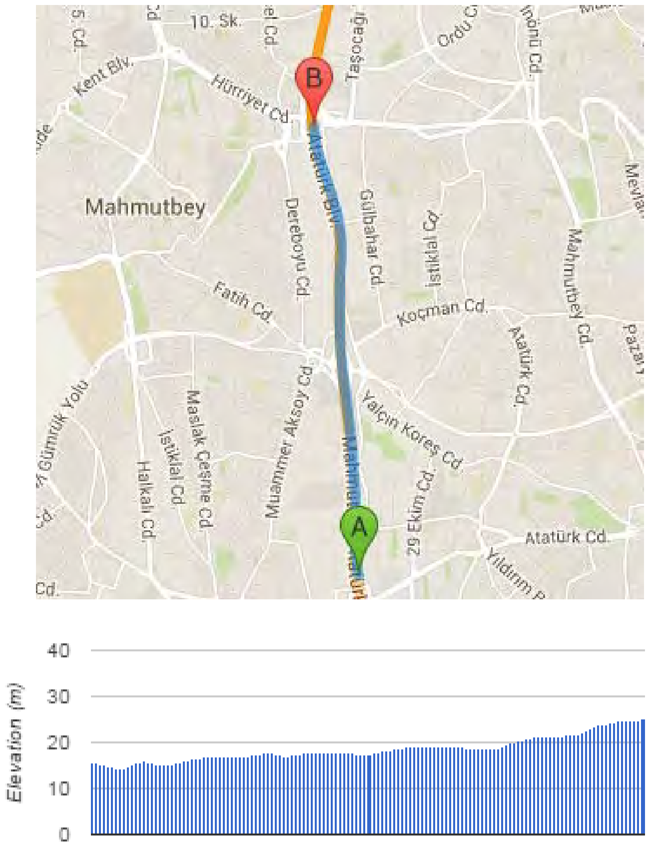

Figure 1: Route 1 and its elevation graph

Data from the vehicle has been collected in real-time using existing on-board diagnostics (OBD2), a Bluetooth interface and a smartphone. An OBD2 protocol allows accessing the vehicle's Engine Control Unit (ECU) easily through a Bluetooth OBD2 connector (see Figure 2). Instant data are obtained via Torque Pro (Play.google.com, 2015) that uses the OBD2 connector. Many recently manufactured vehicles support the use of OBD2. The diagnostic socket should be fitted to the vehicle using an adapter plug prior to instant data collection. Torque Pro is a tool for performance and diagnosis, and runs on the Android phones of any kind. The tool keeps the driver informed via several sensors located within the Engine Management System of the vehicle. Through OBD2, it is possible to access data from the ECU and OBD2 itself becomes an extremely useful source of information for screening and solving problems with the vehicle.

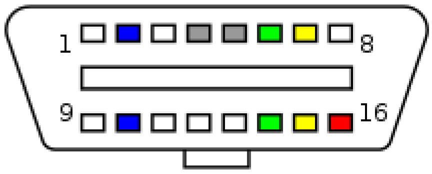

Figure 2: An OBD2 connector and a Bluetooth adaptor

In order to capture the parameters needed by the emission models via Torque Pro, a Bluetooth adaptor is plugged into the OBD2 socket of the vehicle, through which parameters such as the vehicle weight and engine displacement are input into the Torque Pro application on the smart phone.

5. Results

In this section, we present comparisons of the consumption values given by the six models with the CO_2 emission values measured in real-time. The result is shown in Table 1 for the route, in which we present, under column "real-time data", the actual CO_2 emission (in gram) measured under different speed values. We also present the estimations obtained by the six models under their respective columns. We then calculate the Mean Absolute Error (MAE) by calculating the absolute difference between the figures given by the emission model and the real-time measurement for each model and speed level separately, and then taking the average, all of which is provided in Table 2. In this table, the values yielding the best results are highlighted in bold font. Finally, Figure 3 provides a visual depiction of the comparison results, where the horizontal axes are the speeds (in km/h) and the vertical axes show the CO_2 emission (in gram).

Table 1: Comparisons on Route measurements

	CO_2 Emission (gram)						
km/h	**real-time data**	**CMEM**	**PERE**	**FMEFCM**	**IFCM**	**RSFCM**	**VSPM**
45	126,76	229,23	75,97	138,68	304,31	146,63	165,63
60	94,52	140,89	79,50	151,49	261,91	116,60	118,37
75	90,98	143,10	86,57	163,86	228,78	163,86	104,23
90	104,23	149,28	118,81	203,61	262,79	203,61	108,21
105	129,85	163,42	136,03	229,23	296,80	229,23	118,37

Table 2: MAE values of the models on Route

	Mean Absolute Error					
speed (km/h)	**CMEM**	**PERE**	**FMEFCM**	**IFCM**	**RSFCM**	**VSPM**
45	102,47	50,79	**11,93**	177,55	19,88	38,87
60	46,38	**15,02**	56,98	167,39	22,08	23,85
75	52,12	**4,42**	72,88	137,80	72,88	13,25
90	45,05	14,58	99,38	158,56	99,38	**3,97**
105	33,57	**6,18**	99,38	166,95	99,38	11,48
MAE	55,92	**18,20**	68,11	161,65	62,72	**18,29**

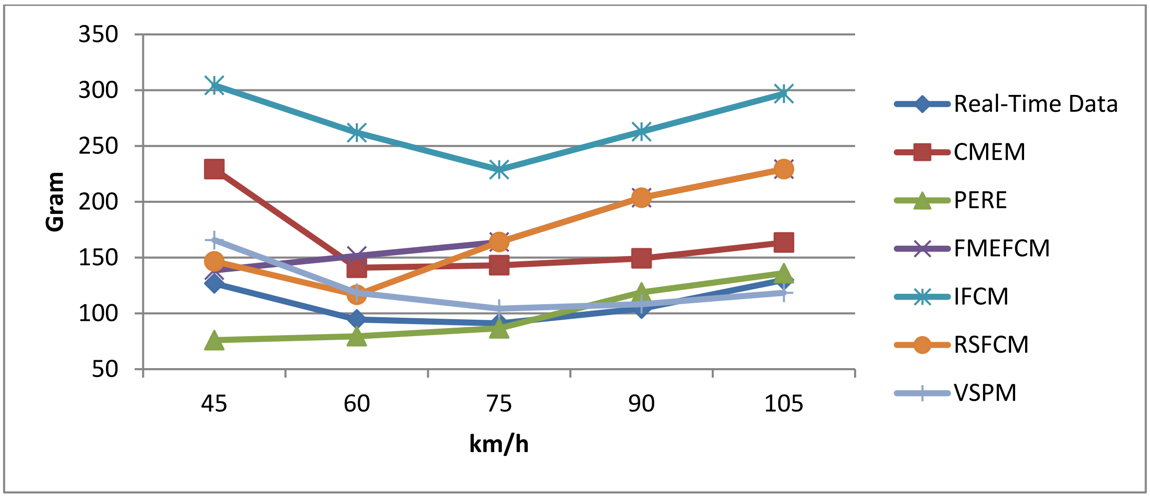

Figure 3: CO_2 Emission curves of all models for the route

The results shown in Tables 1 and 2, and Figure 3, for the route indicate that PERE and VSPM yield estimations that have the least MAE when compared with real data on average. In particular, both models have an MAE about 18, which is significantly less than those of the other four, which range between 55 and 161. It is interesting to note that, in this case, CMEM, FMEFCM and RSFCM provide similar MAE figures, whereas IFCM has the highest.

6. Conclusions

A numerical comparison of six instantaneous emission models from the literature against actual fuel usage data collected from a passenger car suggests that a vehicle power specific model yields the smallest mean error. Of the other formulations, a comprehensive modal emission model and a physical emission rate estimator also provide satisfactory results. For further research, we would suggest that similar tests are performed with different types of vehicle that would enable further comparisons and yield additional insights.

Acknowledgments

This work was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) under project no. 114E421.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

The Impacts of Economic Sanctions on Supply Chain Management: Empirical Analysis of Iranian Supply Chains

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Abstract

Over the last two decades, supply chains have shown a great tendency of expanding their networks beyond the national boundaries and using the global sourcing strategy. As a result, supply chains have become more complex and dynamic networks that extend over several countries. In this situation, any uncertainty in the political and economic relations between countries should be considered as a source of risks. This study has focused on the Iranian supply chains -which have been suffering from harsh economic and financial sanctions- in order to investigate the impacts of such sanctions on supply chains. After identifying the most significant supply chain risks they are analyzed via a qualitative method with respect to the means of probability, impact and effect of sanctions. The impact of sanctions on different risk drivers, industries and supply chain performance measures are investigated. The results show that sanctions have the greatest negative impact on financial risks compared to the other risk drivers and all companies regardless of their industries are found to be vulnerable to sanctions. As to performance criteria however, the analyses disclose that supply chain cost and cash to cash cycle should receive more attention whenever the supply chains are influenced by sanctions. The analyses reveal that supply chain risk factors are really triggered by sanctions specifically risks of exchange rate movements, material price fluctuations, supplier bankruptcy, inability to collect all receivables and buying from a single source which should be viewed as the leading risk factor in the presence of sanctions.

Keywords

Supply chain management, Sanctions, Risk management.

1. Introduction

Over the last two decades, due to the globalization, managers have been facing with unknown conditions and new risks. Having enhanced competitive advantage, supply chains have shown a great tendency of expanding their networks beyond national boundaries and use global sourcing strategy (Giannakis & Papadopoulos, 2016; Sofyalıoğlu & Kartal, 2012). There are many motivations that trigger global sourcing such as accessing to goods with lower prices, better accessibility to the new technologies and greater chance to enter new markets (Holweg et al., 2011; Nassimbeni, 2006). However, this phenomenon leads supply chains to become more complex and imposes them to higher uncertainties and vulnerabilities (e.g. local political instability, exchange rate fluctuations) that may decrease supply chains performance if they are not handled appropriately (Danese et al., 2013; Golini & Kalchschmidt, 2011). In addition, the internationalization of suppliers highlights the role of economic and political relationships between countries. Thus, any political or military conflicts between nations has a huge impact on the firm's business performance. With the escalation of conflicts, one expected action of governments is to institute sanctions. Barriers on imports and exports, financial-related issues, including limitations on financial transactions and reductions in the collaborations with foreign countries are only some of the difficulties which are caused by sanctions (Davarzani & Zegordi, 2011).

However usually sanctions have been imposed against specific activities and entities, due to the multilateral communications between different organizations and industries, in addition to the predetermined goals, other sectors and industries are also affected. For example sanctions against Iran are generally focused on nuclear activities, while their negative effects on the other industries like the automotive industry have been reported (H. Davarzani et al., 2011). From Supply Chain Management (SCM) point of view, economic sanctions are considered as a source of disruptions (unplanned and unanticipated events) which can interrupt the flow of materials, information and cash, leading delays for customers and loos in sales and revenues (Bode & Wagner, 2015). However several author have referred to the sanction, specifically in the field of its effectiveness and its social and humanitarian consequences, the impacts of economic sanctions on the firm's business performance and particularly on the supply chain have been relatively neglected in the literature. This paper has focused on the Iranian supply chains as a case study. Iran has suffered from unprecedented economic and financial sanctions which have been imposed by several nations and international organizations. The main objective of this paper is to implement supply chain risk management by considering the sanction's factor in order to gain a better understanding of the negative impacts of sanctions on different risk factors, risk drivers, industries and supply chain performance measures.

2. Literature review

2.1. Supply chain risk management

In the recent decades, the term "risk" has been explored in different areas such as, finance, decision theory, marketing, management, insurance and psychology (Wagner & Bode, 2006), actuarial science, emergency planning, health care (Sodhi et al., 2012) and recently supply chain. Notwithstanding its long history, there is no comprehensive and encompassing definition of risk (Heckmann et al., 2015; Ho et al., 2015). In the field of SCM different authors have defined supply chain risk (Jüttner et al., 2003; Thun & Hoenig, 2011; Wagner & Bode, 2006; Zsidisin, 2003). Jüttner et al. (2003) define supply chain risk as any risk for the flows of information, material and product from original suppliers to the delivery of the final products for the ultimate user. Although in dictionaries and insurance firms, risk is mostly defined as the possibility of harm, peril or loss, the outcomes of risk are not always negative but could also be positive (Wagner & Bode, 2006). Several authors in the field of SCM only consider the downside potential of risk. Such as Harland et al. (2003) who define risk as a possibility of danger, damage, loss, injury or any other unwanted results. Wagner & Bode (2006) state that according to supply chain business reality, it is better to concentrate only on the "downside" potential of the risk. Based on this view they define risk as "the negative deviation from the expected value of a certain performance measure, resulting in negative consequences for the focal firm" (p.200). Conversely, some authors focus on both the downside and upside potential of the risk. Manuj & Mentzer (2008) for example, define risk as the expected consequences of an uncertain event, i.e. uncertain events lead to the existence of risks.

In the Supply Chain Risk Management (SCRM) literature, there are various categorizations of the supply chain risk and their relevance depend on the chain which has been referred to (Vilko & Hallikas, 2012). Since risk identification is the first step of SCRM (Hallikas et al., 2004; Tummala & Schoenherr, 2011) and a risk categorization system could be helpful for a successful risk identification (Shi, 2004), applying the appropriate categories which can be qualified, weighted and compared has become the most critical step in SCRM (Blackhurst et al., 2008).

Jüttner et al. (2003) categorize supply chain risks into three groups: environmental or external risks as any uncertainties derived from interactions of the supply chain and environment, internal or organizational risks, which are occurred inside the firm and network-related risks, which derive from relationships between the members of the supply chain. Manuj & Mentzer (2008) present a risk classification system with more risk categories including supply, demand, security, macro, policy, competitive and resource risks; however, their risk classification still does not cover all aspects of supply chain. For instance, the relationship risk is not included (Rangel et al., 2014). Tang & Nurmaya Musa (2011), having conducted an extensive literature survey and citation/ co-citation analysis on SCRM, believe that in order to identify and classify the complex risk issues, it is better to divide the supply chain system into sub-systems in terms of financial, information and material flows. They also found out that risks related to information flow have gotten the least amount of attention.

Reducing vulnerability to risks is the key concept behind the risk management. Relatively, SCRM tries to apperceive and elude the adverse consequences of any risky events in the supply chain (Rangel et al., 2014). SCRM is based on the coordination and collaboration of supply chain entities to predict risks for the sake of designing and implementing the proper strategies that would be fit for overcoming the negative effects of such risky events (Elzarka, 2013). However a wide range of qualitative and quantitative process and techniques have been developed and used to manage supply chain risks (Ho et al., 2015), the main components of the majority of them are; risk identification, risk analysis, risk management and risk monitoring and evaluation (T. Wu & Blackhurst, 2009).

2.2. Economic sanctions

Nowadays, sanctions are becoming a common diplomatic tool in the international polices as a visible and less expensive substitute for armed conflicts to change the human rights, trade or foreign policy of another country (Choonara, 2013). The rationales of imposing sanctions have comprised a wide range, from encouraging democracy, stopping violation of human rights, enforcing peace treaty to settling civil wars and preventing the spread of weapons of mass destruction (Eriksson, 2013). The effectiveness and necessity of sanctions have become a controversial subject for not only senders (countries that imposed sanctions) but also targets (sanctioned nations). Since a majority of target countries have not conducted or published any scientific studies on the impact of sanctions in their territory, determining the extent of such impacts is difficult (Lektzian & Patterson, 2015; Office, 2008).

The most researches and studies in the field of economic sanctions are concentrated on two main topics:

- The effectiveness of sanctions to achieve specific diplomatic goals.
- The social and humanitarian consequences of economic sanctions.

According to de Jonge Oudraat (2000), economic sanctions have devastating effects on the target nation's economy. But in many cases, they have not been able to reach their diplomatic goals. Allen (2005) believes that the effectiveness of sanctions is related to the type of the political regime present in the target nation. The lack of democracy in the target country increases the duration of sanctions and reduces their effects. Several reports and studies by the UN and academia show that the consequences of sanctions are not only limited to specific activities or entities of the target's government, rather it is the general public that suffers the most (Karimi & Haghpanah, 2015; Peksen, 2011). In the case of Iran, for instance, notwithstanding the fact that medicine trades are exempted from sanctions, due to money transferring difficulties, sanctions have had detrimental impacts on drug supply and have caused shortages in vital medicines (Mohammadi, 2013).

2.3. Economic sanctions and supply chain management

Over the past few decades, due to the globalization of industries and supply chains, the relationships between countries have had a crucial role in the success of supply chains. Sanctions are directly related to the relations between countries and the occurrence of them has a very huge potential to damage supply chains. The first thing which crosses the mind about sanctions is prohibition on imports and exports; although, it is just the first and immediate impacts. After a while, financial issues will be appeared which lead to restrictions on banking transactions and money transferring. In this situation, firms are not able to participate in international financial activities. Moreover, in the long term sanctions reduce foreign investments and collaborations with international organizations. Since sanctions are limited to certain countries such as Iran, Iraq, North Korea and Cuba, their effects on the target's economy and in particular supply chain has received a little attention in the literature. The limited investigations conducted in this area have mostly been concentrating on the effectiveness of sanctions on changing the target nation's policies and other political issues (Zegordi & Davarzani, 2012).

Sanctions are rare but whenever they are imposed they can severely interrupt or delay financial, material and information flows. The occurrence probability of sanction is not fixed and does not follow any distribution function. In the normal situation, the probability is extremely low but due to some political issues and instabilities it may increase rapidly. As a consequence, firms in the normal circumstances do not have a tendency to invest on mitigation strategies to cope with this type of disruption. But during the period when the probability of sanction being imposed increases, taking extreme actions on conceivable choices are reasonable (H. Davarzani et al., 2011). The effectiveness of sanctions on supply chains just like other disruptions depends on several factors:

- The firm's degree of preparedness (Thun & Hoenig, 2011).
- The supply chain's development and sourcing policy (H. Davarzani et al., 2011).
- The level of collaboration with foreign suppliers (Allon & Mieghem, 2010).

3. Methodology

3.1. Research design

The study takes its starting point from the identification of supply chain risks. In order to identify the most important and common supply chain risks the risk classification system which was proposed by Tang & Nurmaya Musa (2011) was applied. They categorized supply chain risks in terms of material, information and financial flows. Applying this classification system seems to be more appropriate for the objectives of this study because all supply chains regardless of their size and scope have been always involved with such flows. After that to enrich the list of all common risks which may occur in any supply chain, a literature survey was conducted through several reliable sources like scientific journal articles and books. The results of the literature survey which were used to construct the questionnaire of this paper are presented in Table1.

The questionnaire was composed of three sections. The first section was designed to gather the participants' demographic data, including type of industries, job positions and working experience. The second section tried to analyze the risks in terms of their probability of occurrence, consequences and the effects of economic sanctions. Since quantifying these values are hardly possible, a qualitative approach was applied to assess and analyze the identified risks. The last section of the questionnaire was dedicated to evaluate the adverse impacts of economic sanctions on supply chain performance measures.

Table 1: Supply chain risk factors

	Risk factor	Source
Information flow risk	Information security risks (hackers, spyware & etc.)	(Blackhurst et al. (2008); Punniyamoorthy et al. (2013))
	IT/IS out sourcing risks	Faisal et al. (2007)
	Intellectual property theft risk	Faisal et al. (2007)
	Information accuracy	Olson & Wu (2010)
	Inadequate IT system	Aloini et al. (2012)
	Disclosure of information	Ratnasingam (2006)
	Information infrastructure breakdown	Rangel et al. (2014)
Financial flow risks	Exchange rate	(Meulbroek (2002); Tummala & Schoenherr (2011))
	Price & cost fluctuations	Cucchiella & Gastaldi (2006)
	Shortage of cash(lack of liquidity)	Waters (2007)
	Financial strength of supply chain partners	Tang & Nurmaya Musa (2011)
	Inability to not collecting all receivables	Rangel et al. (2014)
	Low profitability	Waters (2007)
Material flow risks (source)	Supplier fulfillment errors(delivery delays & delivery mistakes)	Micheli et al. (2008)
	Inflexibility of supply source	(Ceryno et al. (2014); Punniyamoorthy et al. (2013))
	Quality issues	(Ceryno et al. (2014); Punniyamoorthy et al. (2013))
	Procured from a single source	Tummala & Schoenherr (2011)
	Supplier selection	Tang & Nurmaya Musa (2011)
	Supplier insolvency	Waters (2007)
	Supplier bankruptcy	Ceryno et al. (2014)
	Supplier breach contract agreement	Pujawan & Geraldin (2009)
	Lack of control over supplier	Rangel et al. (2014)
	Financial strength of suppliers	Micheli et al. (2008)
	Inability to quickly implement product & technological changes	Micheli et al. (2008)
	Difficulties in satisfying the demand	Micheli et al. (2008)
	Loss of key suppliers	Waters (2007)
Material flow risks (Delivery)	Forecast error in demand	Punniyamoorthy et al. (2013)
	Unanticipated or very volatile changes in demand	Punniyamoorthy et al. (2013)
	Demand fluctuates seasonally	Wagner & Bode (2006)
	Delay in delivery to customers	Punniyamoorthy et al. (2013)
	Changes in customers tastes	Ceryno et al. (2014)
	Customer insolvency	Pfohl et al. (2010)
	Cost of holding inventories	Tummala & Schoenherr (2011)
	Rate of product obsolescence	Tummala & Schoenherr (2011)
	Bullwhip effect	Ceryno et al. (2014)
	Reputation risk or confidence loss in product or brand	Rangel et al. (2014)
	Lack of transportation capacity	Pfohl et al. (2010)
	Logistic outsourcing risks	Drewry (2009)
	Higher cost of transportation	Tummala & Schoenherr (2011)
	Port issues	Tummala & Schoenherr (2011)
	Border crossing & customs regulations	Blackhurst et al. (2008)
	Theft & cargo loss or damage	Drewry (2009)

	Risk factor	Source
Material flow risks (make)	Inadequate production capability	Punniyamoorthy et al. (2013)
	Inflexibility in capacity	Tummala & Schoenherr (2011)
	Disruption in production	Tang & Nurmaya Musa (2011)
	Weakness in the planning & control of production & inventory	Rangel et al. (2014)
	Machine breakdown	Sudeep & Srikanta (2014)
	Service, maintenance & spares	Waters (2007)
	Critical equipment & tools	Waters (2007)
	Technological backwardness	Sudeep & Srikanta (2014)
	Lack of skilled workers	Vilko & Hallikas (2012)
	Labor strikes	Vilko & Hallikas (2012)
	Carelessness & lack of motivation among the workforce	Vilko & Hallikas (2012)
	Health & safety issues	Waters (2007)
	Accidents (fire…)	Waters (2007)
	Customer health & product safety	Ceryno et al. (2014)
	Product & process design risks	Tang & Nurmaya Musa (2011)
	Shortage of material	Pujawan & Geraldin (2009)
	Interrupted gas/electricity supply	Pujawan & Geraldin (2009)
	R&D uncertainty	Ceryno et al. (2014)
	Technological changes	Cagliano et al. (2012)
	Poor quality	Sudeep & Srikanta (2014)
	Hesitation in sharing of design & other documents with suppliers	Punniyamoorthy et al. (2013)
	higher product cost	Tummala & Schoenherr (2011)
Socio-political risks	Fiscal & monetary reforms	Ceryno et al. (2014)
	Trade restrictions	Ceryno et al. (2014)
	Strict safety regulations	Rangel et al. (2014)
	Strict environmental policies	Waters (2007)
	Economic sanctions	Ceryno et al. (2014)
	Political instability	Ceryno et al. (2014)
	Democratic changes in government	Ceryno et al. (2014)
	War/Revolution	Waters (2007)
	Terrorist attack or Sabotage	Waters (2007)
	Social unrest	Blackhurst et al. (2008)
	Changing social concerns	Ceryno et al. (2014)
Macroeconomi	Energy price volatility	Meulbroek (2002)
	Inflation	Meulbroek (2002)
	Interest rate	Ceryno et al. (2014)
	Currency devaluations	Meulbroek (2002)
	Tax & tariff changes	Rangel et al. (2014)
	Material prices fluctuations	Rangel et al. (2014)
	Oil price	Meulbroek (2002)
	Climate change	Vilko & Hallikas (2012)
	Natural disasters	Vilko & Hallikas (2012)

The questionnaire used three five-point Likert scales to estimate probability, consequence and economic sanctions of each identified risk. This helps the participants to determine the consent to a specific statement. Tables 2, 3 and 4 illustrate the classification for probability, consequence and economic sanctions.

After specifying ranges of probability, consequence and economic sanctions by participants, the risk score was calculated by multiplying the three mentioned measures.

Table 2: Illustrative probability scale

Descriptor	Description	Frequency	score
Certain	Event is expected to happen	Has occurred more than 4 times a year	5
Likely	Event is likely to occur	Has occurred 3 or 4 times a year	4
Possible	Event may occur at sometime	Has occurred 1 or 2 times a year	3
Unlikely	Event is unlikely to occur	Has occurred once in 1 or 2 years	2
Rare	Event is highly unlikely	Has occurred once in more than 3 years	1

Table 3: Illustrative impact scale

Descriptor	Description			score
	People	property	Financial	
Catastrophic	Multiple deaths(employees, customers, vendors)	Destruction or loss of > 50% of total assets	Financial loss of > 50% of annual profit	5
Major	Single death or multiple major injuries	Major damage to property or loss of < 50% of total assets	Financial loss of < 50% of annual profit	4
Moderate	Major injury requiring hospitalization	Damage or loss of <20% of total assets	Financial loss of < 20% of annual profit	3
Minor	Injury requiring medical treatment	Loss of <10% of total assets	Financial loss of < 10% of annual profit	2
Insignificant	Minor injury requiring first aid treatment	Minor damage to property	Negligible lost profit	1

Table 4: Illustrative economic sanctions scale

Descriptor	Description	score
Integral	Economic sanctions are the only source of the risk	5
Very strong	There is a very strong connection between the risk and economic sanctions	4
Strong	There is a strong connection between the risk and economic sanctions	3
Limited	There is a restricted connection between the risk and economic sanctions	2
Irrelevant	There is no connection between the risk and economic sanction	1

To reach the purpose of this research, 64 companies located in Iran were selected. The chosen companies belong to different industrial sectors including, automotive, medical, food, electronic and others. Having enough knowledge about supply chain, risk management and implementation of supply chain or logistics management were the main criteria to select the case companies. In order to collect reliable and accurate data, it is important that all participants have not only an extensive understanding about the concept of SCM and risk management but also a comprehensive information about their company's operations. For this reason, the participants were asked to identify individuals who would be appropriate to response the questionnaire.

3.2. Research hypotheses

Modern supply chain systems are complex and dynamic networks that extended over several geographical districts, including multiple tiers of suppliers, each of which may have various entities with different operations, structures and goals. Such systems are vulnerable to a wide range of internal and external risks (Aqlan & Lam, 2015; Teresa Wu et al., 2006). Sanctions as one of the external supply chain risks have a great potential to cause several limitations, including difficulties in importing and exporting, restrictions on transportation of purchased/ sold items, reducing number of suppliers, lack of access to International financial markets and banks. These limitations may have impacts on the focal firm, the whole chain and even the marketplace (Christopher & Peck, 2002). Furthermore, such risk can scarcely be affected and conducted directly or indirectly inside the supply chain (Thun & Hoenig, 2011). In this study four hypotheses have been formulated to investigate the effects of financial and economic sanctions on supply chains:

- H 1: Supply chains are regarded as being more vulnerable due to sanctions.
- H 2: Sanctions have different impact on various supply chain risk drivers.
- H 3: Sanctions have different impact on different industries.
- H 4: The occurrence probability of supply chain risks have been increased due to sanctions

4. Analysis

4.1. Profile of questionnaire respondents

Among the 64 selected companies, 34 participated in the study. Among the respondents, 16 participants filled out the questionnaire by email and 18 of them were participated in face-to-face interview. The total response rate in the study was 53%. The participants had a wide range of duties and varied in terms of job title. Related to the working experience, the average respondent's working experience was 14 years. The high level of working experience and their position show that their opinions are trustworthy and representative. Table 5 presents an overview of respondent attributes.

Table 5: Respondent attributes

Industry type	Frequency	(%)	Job title	Frequency	(%)	Experience	Frequency	(%)
Automotive	7	20.59	CEO	4	11.76	1-5 years	2	5.88
Medical	4	11.76	Purchasing manager	6	17.65	6-10 years	9	26.47
Electronic	7	20.59	Operations manger	6	17.65	11-15 years	10	29.41
Manufacturing	6	17.65	Project manager	2	5.88	16-20 years	11	32.35
Food	4	11.76	Logistics manager	3	8.82	more than 20 years	2	5.88
Construction	3	8.82	Quality manager	1	2.94			
Others	3	8.82	Commercial manager	7	20.59			
			Technical manager	1	2.94			
			Others	4	11.76			

4.2. Risk analysis

Risks were assessed by experts in terms of their probability, impact and economic sanctions in order to prioritize them. Table 6 shows the descriptive statistics of the top 20 ranked supply chain risks in the present of sanctions. In this table the mean, standard deviation and rank of each individual risk in terms of probability, impact, economic sanctions and risk score are calculated.

Table 6: Statistical results of risk assessment

Risk factor	Probability			Impact			Sanctions			Risk score		
	Mean	S.D	Rank	Mean	S.D	Rank	Mean	S.D	Rank	Mean	S.D	Rank
Exchange rate	3.79	1.04	1	3.15	1.10	15	3.76	0.89	1	49.15	33.99	1
Material prices fluctuations	3.53	1.11	3	3.38	1.16	9	3.35	1.25	9	48.24	35.23	2
Supplier bankruptcy	2.59	1.23	28	3.79	1.20	1	3.68	1.27	2	46.41	38.35	3
Inability to not collecting all receivables	3.53	1.13	2	3.71	1.00	3	3.24	1.02	11	46.03	29.11	4
Procured from a single source	3.21	1.15	8	3.29	1.06	10	3.50	1.11	4	42.56	28.04	5
Inflation	3.29	1.24	6	2.79	1.15	33	3.35	1.23	8	40.15	37.78	6
Energy price volatility	3.32	1.17	5	2.74	1.14	36	3.32	1.04	10	37.09	33.83	7
Shortage of cash(lack of liquidity)	3.09	1.19	12	3.59	1.02	4	3.03	0.94	16	35.50	28.66	8
Technological backwardness	2.74	1.24	22	3.26	1.05	12	3.35	1.28	7	35.12	26.16	9
Quality issues	3.24	0.82	7	3.5	1.08	5	2.88	1.07	18	34.91	21.93	10
Trade restrictions	2.50	1.21	33	2.79	1.27	32	3.62	1.21	3	33.38	31.45	11
Price and cost fluctuations	3.15	1.26	10	2.91	1.14	25	2.85	1.21	20	32.91	28.26	12
Customer insolvency	3.35	1.07	4	3.26	0.96	13	2.79	1.15	23	32.76	22.69	13
Interest rate	3.15	1.18	11	2.85	1.18	31	3.09	1.16	15	32.76	31.18	14
Currency devaluations	3.06	1.28	16	2.65	1.15	41	3.24	1.16	13	32.65	27.96	15

According to Table 6, the risk of currency fluctuation was the top concern of supply chain executives. In case of Iran, global financial sanctions are considered to be the main reason of experiencing such a huge fluctuations in foreign currencies. The second-highest concern among supply chain decision makers in Iran was raw material price fluctuations. Raw material cost is considered as one of the main elements in the cost of product especially in the process industries where 50 to 60 % of overall costs of manufacturers derive from raw materials (Leybovich, 2012). In this situation, in order to increase the earning margins, improve security of supply and enhance supply chain operations, companies need to implement an appropriate raw material management. Supplier bankruptcy, inability to collect all receivables and procuring from a single source were the other important risks among companies in Iran.

4.3. Effect of sanctions

After assessing supply chain risks, the participants were asked for their estimation concerning the vulnerability of their supply chain with regards to the economic sanctions. The mean value of all participants was 3.53 on the five-point Likert scale (1 is no effect, 2 is low, 3 is moderate, 4 is high and 5 is very high negative effect). 55.8% of respondents regarded their supply chain as being highly vulnerable due to the sanctions (point 4 or 5). Only 5.9% of them estimated that economic sanctions had little or no negative effects on their supply chain (point 1 or 2 on the Likert scale). The individual Likert items was used to gather data for this part. So, utilizing the Wilcoxon Signed Rank Test seems more appropriate for the first hypothesis. This test determines whether the median of answers differs significantly from a specific value or not. The results in Table 7 show that the median is greater than 3 (P-value = 0.001). In the other words, the majority of participants believed that their supply chain was more vulnerable as a results of sanctions. Thus, H1 cannot be rejected.

Table 7: Wilcoxon test for H1

N	N for test	Wilcoxon Statistic	p	Estimated median
34	21	210.0	0.001	3.500

In addition, in order to understand which ones of the supply chain performance measures are mostly affected by the sanctions, the participants were asked to give their estimations with regards to each of the performance measure. The results obtained from participants' responses are shown in Figure 1.

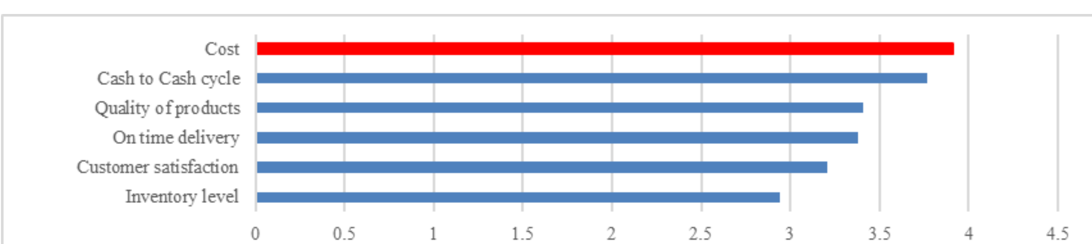

Figure 1: Supply chain performance measures

As illustrated in Figure 1, the sanctions have caused the increment in the production costs becomes the main concern of the Iranian manufacturers. Increased costs of trading and transactions due to denial of the LCs of Iranian banks, the rising cost of insurance and freight costs are among possible reasons for increased cost of production of firms in Iran.

In the next step, the effects of sanctions on different supply chain risk drivers were investigated to see whether all risk drivers are equally affected by sanctions or not? According to the results, 98.6% of participants believed that economic sanctions have no or limited impacts on natural disasters risks. On the other hand, 65.6%, 64.6% and 54.7% of participants believed that sanctions have strong effects on financial, macroeconomic and Socio-political risk drivers, respectively. One way ANOVA was applied to test the second hypothesis (H2). Since for testing this hypothesis several Likert questions which have the same Likert scale are summed, parametric statistical tests such as analysis of variance based on the Central Limit Theorem can be applied. The results of ANOVA are shown in Table 8.

Table 8: Results of ANOVA related to risk drivers

Source	Sum of Squares	df	Mean Square	F_0	Sig.
Corrected model	17.968	5	3.594	11.758	.000
Intercept	172.777	1	172.777	565.321	.000
Risk Drivers	17.968	5	3.594	11.758	.000
Error	23.533	77	0.306		
Total	477.724	83			
Corrected Total	41.502	82			

Since p-value is very small (p-value < 0.05), it can be stated that the sanctions have significant different impacts on the risk drivers. In the other words, the second hypothesis cannot be rejected. The results of the Tukey multiple comparisons show that financial risks, macroeconomic risks and Socio-political risks are significantly different (p-value <0.05) from other risk drivers and are mostly impacted by sanctions (see Table 9).

Table 9: Results of ANOVA related to risk drivers

Risk drivers	Risk drivers	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Information risks	Financial risks	-1.5048*	.30757	.000	-2.4037	-.6058
	Material risks	-.6310	.22283	.063	-1.2823	.0202
	Socio-political risks	-1.2214*	.27244	.000	-2.0177	-.4252
	Macroeconomic risks	-1.5643*	.29550	.000	-2.4280	-.7006
	Natural disasters	.4836	.44325	.884	-.8119	1.7791
Financial risks	Information Risks	1.5048*	.30757	.000	.6058	2.4037
	Material risks	.8737*	.23860	.006	.1764	1.5711
	Socio-political risks	.2833	.28548	.919	-.5511	1.1177
	Macroeconomic risks	-.0595	.30757	1.000	-.9585	.8394
	Natural disasters	1.9883*	.45139	.000	.6691	3.3076
Material risks	Information Risks	.6310	.22283	.063	-.0202	1.2823
	Financial risks	-.8737*	.23860	.006	-1.5711	-.1764
	Socio-political risks	-.5904*	.19119	.032	-1.1492	-.0316
	Macroeconomic risks	-.9332*	.22283	.001	-1.5845	-.2820
	Natural disasters	1.1146	.39850	.069	-.0501	2.2793
Socio-political risks	Information Risks	1.2214*	.27244	.000	.4252	2.0177
	Financial risks	-.2833	.28548	.919	-1.1177	.5511
	Material risks	.5904*	.19119	.032	.0316	1.1492
	Macroeconomic risks	-.3429	.27244	.806	-1.1391	.4534
	Natural disasters	1.7050*	.42822	.002	.4534	2.9566
Macroeconomic risks	Information Risks	1.5643*	.29550	.000	.7006	2.4280
	Financial risks	.0595	.30757	1.000	-.8394	.9585
	Material risks	.9332*	.22283	.001	.2820	1.5845
	Socio-political risks	.3429	.27244	.806	-.4534	1.1391
	Natural disasters	2.0479*	.44325	.000	.7524	3.3434
Natural disasters	Information Risks	-.4836	.44325	.884	-1.7791	.8119
	Financial risks	-1.9883*	.45139	.000	-3.3076	-.6691
	Material risks	-1.1146	039850	.069	-2.2793	.0501
	Socio-political risks	-1.7050*	.42822	.002	-2.9566	-.4534
	Macroeconomic risks	-2.0479*	.44325	.000	-3.3434	-.7524

The one-way ANOVA was used again to investigate how sanctions might affect different industries. Results of ANOVA is presented in Table 10. Table 10 shows that all industries regardless of their type, size and scope are negatively affected by the sanctions. And, there is not enough evidence to conclude that sanctions have a significant effect on different industry types (p-value= 0.175 which is greater than 0.05). Thus, the third hypothesis (H3) is rejected.

Table 10: Results of ANOVA related to industry type

Source	Sum of Squares	df	Mean Square	F_0	Sig.
Corrected model	2.819	6	.470	1.638	.175
Intercept	152.103	1	152.103	530.363	.000
Industry types	2.819	6	.470	1.638	.175
Error	7.743	27	.287		
Total	190.222	34			
Corrected Total	10.563	33			

Furthermore, the participants were asked to give their estimation about the effect of sanctions on the occurrence probability of other disruptions in their supply chain. The mean value of all participants was 3.5 on the five-point Likert scale (1 means sanctions have no effect, 2 means sanctions have a low effect, 3 means sanctions have a moderate effect, 4 means sanctions have a high effect and 5 means sanctions have a very high effect on increasing the occurrence probability of supply chain risks). Almost 94.1% of the firms believed that the occurrence probability of supply chain risks has been increased due to the sanctions (point 3, 4 or 5 on the Likert scale) and only 5.9% of the managers stated that there is little or no relation between sanctions and the occurrence probability of supply chain risks (point 1 or 2 on the Likert scale). Same as the first hypothesis the individual Likert items was used to gather data for this part. Therefore, the Wilcoxon test was applied to see whether the median of answers differs significantly from specific value or not. The result of the Wilcoxon test in Table 11 shows that the median is greater than 3 (P-value = 0.001 less than 0.05). In other words, the most of participants believed that the occurrence probabilities of supply chain risks have been increased due to the sanctions. So, the last hypothesis (H4) cannot be rejected.

Table 11: Wilcoxon test for H4

N	N for test	Wilcoxon Statistic	p	Estimated median
34	20	190.0	0.001	3.500

5. Conclusion

This study was focused on the Iranian firms - which are highly impacted by several strict and multilateral economic and financial sanctions - to implement SCRM by considering the sanction's factor, investigate on the effects of sanctions on different supply chain risk drivers and identify top ranked risks.

The results of this study can be summarized as:
First, the empirical analysis discloses that Iranian supply chains are mostly viewed as being vulnerable to sanctions. Limitations caused by sanctions such as; difficulties in importing and exporting, restrictions on transportation of purchased/sold items, reducing number of suppliers, lack of access to international financial markets and banks are the factors that increase supply chain vulnerability.

Second, top five ranked supply chain risk in the presence of sanctions are:

- Exchange rate
- Material prices fluctuations
- Supplier bankruptcy
- Inability to collect all receivables
- Procured from a single source

Third, the results reveal that sanctions have the greatest negative impact on the financial and macroeconomic risk drivers compared to other supply chain risk drivers. Fourth, the study discloses that the occurrence probability of supply chain risks are increased due to sanctions. In addition to direct consequences of sanctions on supply chains such as increasing the cost of material supply and logistics, diminishing the access to specific materials, equipment and technologies under sanctions circumstances, the occurrence probability of other disruptions like exchange rate, commodity prices volatility, lack of liquidity and bankruptcy are sharply increased. Fifth, the results show that supply chain performance measures have been also adversely affected by sanctions. Among all investigated performance criteria, supply chain cost and cash to cash cycle should receive more attention. Finally, according to the countries imposing sanctions against Iran, only certain industries such as the nuclear industry and oil and gas sectors have been the targets of sanctions. But the analysis shows that all investigated industries are vulnerable to the direct and indirect consequences of sanctions. The multilateral relations and communications between different industries and sectors of a country might be a reason for this fact.

The results of this study prepare a worthy and useful information for practitioners. First, the findings from this study provide a comprehensive and intensive list of supply chain risks that can be used by different industries to start the SCRM process. Second, this study enhances the awareness of the practitioners about the risks that must be taken into consideration when economic and financial sanctions have been imposed against their supply chain. Finally, this study has disclosed that among all supply chain risk drivers, sanctions had the most adverse effects on financial and macroeconomic risks. So, supply chain managers should pay more attention to such risks. It is needed to mention that, although this study was carried out among several supply chains in different industries, the research approach provides evidence for merely a single country, which limits the extent to which the results can be generalized.

This study has highlighted a number of areas meriting future studies:

- The occurrence and consequences of sanctions are generally beyond the control of supply chain executives. In this situation, the role of government's economic and political policies becomes more prominent in the effectiveness of sanctions. So in the future studies the role of government measures to reduce or increase the effects of sanctions, particularly on the supply chains can be investigated.
- Sanctions usually are imposed for an interim period of time. After the lifting of sanctions, firms should return to their normal business in the shortest time. Assessing and proposing the best strategies and action plans to help supply chains in this step can be studied in the future researches.
- The results of this study showed that sanctions have negative impacts on the supply chain performance measures. More empirical studies are needed to determine the exact impact of sanctions on different performance measures.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Solving a New Multi-Objective Multiple Allocation Hub Covering Location Problem with a Ring-Structured Hub Network by the NSGA-II

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Abstract

Hub location problems have wide applications in different areas of transportation, telecommunication, postal and cargo delivery systems. In telecommunication area, networks do not operate necessarily on a complete hub network and can configure different structures (e.g., tree, star, path and ring). For instance, ring-structured optical networks are very important because this kind of configuration has a self-healing property. As a result, this paper presents a new multi-objective mathematical model for the multiple-allocation hub covering location problem with a ring-structured hub network. Due to the computational complexity of the presented NP-hard model and achieving the near-optimal Pareto solutions, a multi-objective non-dominated sorting genetic algorithm (NSGA-II) is used. To tune its parameters, a response surface methodology (RSM) is used. Then, computational trials for test problems, including small and large -sized instances generated from the Turkish dataset, are solved by an exact method (i.e., ε-constraint method) for small instances and the NSGA-II for large instances. The performance of the NSGA-II is evaluated by comparing the resulted Pareto solutions of both methods. The satisfying results show that the algorithm ensures good performance. Moreover, a sensitivity analysis is conducted to determine the sensitivity of solutions on various values of the parameters.

Keywords

Hub covering location, ring-structured hub network design, multi-objective evolutionary algorithm, response surface methodology, ε-constraint method

1. Introduction

Hub location is extensively applied in transportation, telecommunication, postal and cargo delivery systems. In these systems, hubs are intermediates for transmitting the flows instead of sending them directly through all origin-destination pairs (EghbaliZarch et al., 2013). A telecommunication area is originally considered as one of the oldest application of hub network concept (Farahani et al., 2013). A communication network is a set of nodes that transmit messages or information over different kind of links (e.g., copper cables, fiber-optic cables or satellite links) (Klincewicz, 1998). Hubs are special elements, which benefit networks by switching, distributing, concentrating flows and designing robust and cost-effective networks (Klincewicz, 1998). In telecommunications, networks do not operate on a complete hub network because of unnecessary high hub network designing investment costs and hubs can configure different structures such as tree, star, path or ring (Klincewicz, 1998; Calik et al., 2008). Klincewics (1998) mentioned that ring structure, especially SONET rings in telecommunication networks, have increasing importance because of the self-healing properties associated with them. As it is shown in figure 1, SONET rings, one of ring-structured hub network examples, use two transmission paths between network nodes, working and standby rings. The working ring handles all data traffic, and the standby or protection ring remains on standby. When the working ring fails, automatically detect the failure and transfer control to the protection ring in a fraction of a second. The previous explanations define self-healing characteristic of SONET ring technology. In these networks, hubs are typically digital cross-connects (DCSs) or add/drop multiplexers (ADMs).

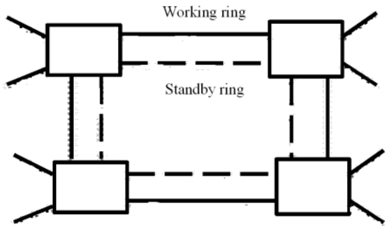


Figure 1: Example of a SONET ring network

Klincewicz (1998) provided a perfect review of the hub location network design and discussed certain key issues in modeling hub location problems in the particular context of communications networks and proposed possible avenues for future works. In this paper by considering the network design approach, one of the previous future study directions, ring-structured hub network, in the multiple allocation hub covering location is developed and a novel model is proposed. To investigate the various aspects of the problem a broad analysis has been performed. The remainder of this paper is organized as follows. Section 2 presents a brief review of the literature on hub covering location problem. After defining the problem and developing a mixed-integer linear programming in Section 3, the solution approach for the model including the ε-constraint method and applied NSGA-II algorithm are provided in Section 4. Computational results are reported in Section 5, and finally conclusions are remarked in Section 6.

2. Literature Review

In this section, we review the literature of the hub location problem. Zanjirani Farahani et al. (2013) focused on reviewing of all variants of HLPs (i.e., network, continuous, and discrete HLPs; in particular, mathematical models, solution methods, main specifications, and applications of HLPs). We classify the required background into two following separate but complementary streams:

2.1. Hub Covering Location Problem

The hub location problem was first introduced by O’Kelly in 1986. Hub covering location problem is one of the hub location problem categories that only a few authors have worked on it (Alumur & Kara, 2008b). Campbell (1994) introduced hub covering location for the first time and defined three types of coverage for the hubs;

I. The cost (time or distance) from origin i to destination j via hubs k and l does not exceed a specific value.

II. The cost (time or distance) for each link in the path from origin i to destination j via hubs k and l does not exceed a specific value.

III. The cost (time or distance) for each link in the path from origin i to hub k or hub l to destination j does not exceed a specific value.

Tan and Kara (2007) put the latest arrival hub covering in to use the cargo delivery sector in Turkey. Alumur and Kara (2008a) considered a hub covering problem over the incomplete hub network focusing on cargo application. Calik et al. (2009) studied single allocation hub covering problem over incomplete hub networks and proposed a tabu-based heuristic algorithm. Ghodratnama et al. (2014) studied a robust environment with a novel p-hub covering problem that considered production facilities located in the hubs and vehicle transporters that ship commodities. Sedehzadeh et al. (2014) presented a new priority M/M/c queuing hub covering problem. Due to the computational complexity of the model, they proposed a multi-objective parallel simulated annealing (MOPSA) algorithm. Nikokalam-Mozafar et al. (2014) presented a stochastic bi-objective model for a single-allocation hub covering problem (HCP) with the variable capacity and uncertainty parameters and it was solved by multi-objective invasive weed optimization.

2.2. Ring-Structured Hub Network

One of the main assumptions of a typical hub location problem is that the hub network is complete while this is not a realistic assumption in real life. In public transportation and telecommunication areas, networks do not operate on a complete hub network and they can configure different structures such as tree, star, path or ring. In the ring topology, each hub node only links with two hubs so there is only one cycle in the hub network (Karimi & Setak, 2014). In most hub location models, fully connected hub network is considered as a basic assumption. But in hub location literature, there are some articles that relaxed completed graph of hub network. Klincewicz (1998) provided a perfect review of hub location network design and discussed certain key issues in modeling hub location problems in the particular context of communications networks. Lee et al.

(1993) suggested a two-level hierarchical network topology with the first level (i.e. Connections between hubs) hub-ring and the second level (i.e., Connections between non-hubs and hubs) star-type connections which it creates single allocation strategy. The problem is formulated into a mixed integer programming. Furthermore, Chiu et al. (1995) proposed this structure in hub network problems. Wang et al. (2006) also used ring topology in the telecommunications systems. Karimi and Setak (2014) offered a model to the multiple allocations of the hub location problems, under the incomplete hub location-routing network design. This model was easily transformed to the other hub location problems using one or more constraints.

3. Multi-Objective Mathematical Model

In this section, we define the problem and propose a novel model for a hub covering problem with a ring-structured hub network. Assume that *N* is a given node set with *n* nodes. *P* is the number of hubs that must be located. The model locates *(P>3)* hubs and constructs the ring hub network based on the definition of cyclic graph. In cyclic graph the number of vertices equals the number of edges, and every vertex has degree 2; that is, every vertex has exactly two edges incident with it (Chatrand & Oellermann, 1993). Then remained nodes are allocated to *r* located hubs such that the establishment cost of each origin-hub and hub-destination is less than a given bound (hub radius). In this model third coverage type that represented by Campell (1994) is applied. In telecom application, transmission between hubs is not a concern due to the using technology (Karimi & Bashiri, 2011). This model minimizes the total costs of establishing hubs and links and the total link distances altogether. Klincewicz (1998) suggested homing to multiple hubs as a solution for designing a robust network that continues to function in the event that a particular network element fails; it means that for having reliable networks, it requires more than one connection between non-hub nodes and hubs. So, in this model each node can be allocated to exactly *r* hubs *(r∈{1,…, P})*. The objective of this model simultaneously minimizes the total cost of establishing hub facilities and arcs (links) and the total distance of all links.

Parameters:

n is the number of nodes in the network.

p is the number of hubs that must be located.

r is the number of hubs that each non-hub node can be allocated to.

θ is the cover radius of each hub.

C_{ij} is the fixed cost of establishing a link (arc) between node *i* and node *j*.

D_{ij} is distance of arc (i, j).

F_k is the Fixed cost of establishing a hub at node *k*.

Decision variables:

X_{ik} is a decision variable with value 1 when node *i* is allocated to hub *k*, Consistent with the literature, if, $X_{kk} = 1$ it means that node *k* is a hub.

Y_{ij} is a decision variable with value 1 when hub *i* and *j* are connected to each other and flow orients from *i* to *j*.

In the proposed mathematical model, the objective function (1) minimizes the total costs of establishing hubs and arcs. Objective function (2) minimizes the total distance of all links. By considering the previous defined parameters and decision variables, the model is formulated below:

$$\text{Min} \sum_k F_k X_{kk} + \sum_i \sum_k C_{ik} X_{ik} + \sum_i \sum_{j>i} C_{ij} Y_{ij} \tag{1}$$

$$\text{Min} \sum_i \sum_k D_{ik} X_{ik} + \sum_i \sum_{j>i} D_{ij} Y_{ij} \tag{2}$$

s.t.

$$\sum_k X_{ik} + (r-1) X_{ii} = r \qquad \forall i \tag{3}$$

$$X_{ik} \leq X_{kk} \qquad \forall i, k \tag{4}$$

$$\sum_k X_{kk} = p \tag{5}$$

$$C_{ik} X_{ik} \leq \theta \qquad \forall i, k \tag{6}$$

$$Y_{ij} = Y_{ji} \qquad \forall i, j \tag{7}$$

$$2Y_{ij} \leq X_{ii} + X_{jj} \qquad \forall i, j \tag{8}$$

$$\sum_i \sum_j Y_{ij} = 2p \tag{9}$$

$$Y_{jj} = 0 \qquad \forall j \tag{10}$$

$$\sum_j Y_{ij} = 2X_{ii} \qquad \forall i \tag{11}$$

$$2 - Y_{ij} \geq Y_{ik} + Y_{kj} \qquad \forall i, k, j \tag{12}$$

$$X_{ik} \in \{0,1\} \qquad \forall i, k \tag{13}$$

$$Y_{ij} \in \{0,1\} \qquad \forall i, j \tag{14}$$

Constraint (3) shows each node can be allocated to *r* located hubs. Constraint (4) ensures that a node can be allocated only to a hub. Constraint (5) states that only *p* hub can be established. Constraint (6) is a cover constraint that controls the establishment costs of each origin-hub and hub-destination to be less than a given bound (hub radius). Constraints (7) to (12) configure the ring hub network. Constraint (7) ensures that flow can be directed from *i* to *j* and *j* to *i*. Constraint (8) forces the hub link (*i*, *j*) to be zero unless hub facilities establish at node *i* and *j*. Constraint (9) ensures that just 2*p* hub link can be established. Constraint (10) shows there is no link from hub *j* to *j*. Constraints (11) and (12) ensures the graph connectivity. For example in the network with 6 hubs, Constraint (12) eliminates that kind of possibilities that are shown in figure 2. Constraints (13) and (14) guarantee that the variables are binary.

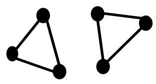


Figure 2: Eliminated possibilities by Constraint (12)

4. Solution Approach

Hub location problems are well-known as NP-hard problem (Alumur & Kara, 2008b) and the presented model is a bi-objective integer linear programming. Consequently, the obtaining optimal solution is computationally hard. Therefore, the model is solved using epsilon constraint method; then, NSGA-II meta-heuristic algorithm is used to solve the resulted problem for larger problems to obtain the near-optimal Pareto solutions

4.1. Epsilon Constraint Method

To deal with multi-objective problems, epsilon constraint method can be counted as one of the well-known approaches which transfers all objective functions into constraints and keeps only one of them in each phase as objective function (Ehrgott & Gandibleux, 2002). In this case, Pareto frontier can be structured with ε-constraint method (Bérubé et al., 2009).

$$Min\, f_1(x)$$

s.t.

$$C(x) \leq 0$$

$$f_1(x) \leq \varepsilon_1$$

$$f_2(x) \leq \varepsilon_2$$

...

$$f_n(x) \leq \varepsilon_n$$

1. Designate one of the objective functions as the main one and let the others appear as the model constraints.
2. Solving the model with each objective function one by one and computing the optimal and nadir values of each objective function.
3. Computing the range between optimal and nadir values of each subsidiary objective functions and dividing this range into a pre-specified number and a schedule of values is obtained for $\varepsilon_1, \varepsilon_2, ..., \varepsilon_k$.

4. Solving the model with main objective function and one of the $\varepsilon_1, \varepsilon_2, ..., \varepsilon_k$, iteratively and reporting the Pareto solutions.

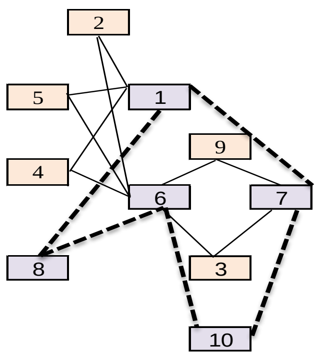
4.2. Non-Dominated Sorting Genetic Algorithm (NSGA-II)

Deb (2002) proposed a computationally fast and elitist multi-objective evolutionary algorithm (MOEA) based on a non-dominated sorting approach named non-dominated sorting genetic algorithm (NSGA-II). The ability of this algorithm is maintaining a better spread of solutions and better converging into the obtained non-dominated front. During the optimization procedure, a parent population is generated randomly as an initial population. After performing the evaluation operation (i.e., calculating the objective function values), all solution should be ranked according to their non-domination level. Offspring population is created by using binary tournament selection, crossover, and mutation operators. These two populations are combined and sorted according to non-domination. The new population of the next generation is selected based on elitism by means of rank and crowding distance of each solution in the population.

4.2.1. Solution Representation and Decoding Method

A solution representation is one of the important parts of designing a meta-heuristic algorithm. For demonstrating the solution of the proposed problem, a two-part chromosome is used to describe the location of hub nodes, the allocation of non-hub nodes to the located hubs and the configuration of the ring-structured hub network. Figure 3 shows the encoding of a network with 10 nodes and 5 hubs. In this chromosome, each non-hub node is allocated to two hubs.

X_{ik}	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	1	0	0	0	0
3	0	0	0	0	0	1	1	0	0	0
4	1	0	0	0	0	1	0	0	0	0
5	1	0	0	0	0	1	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	1	1	0	0	0
10	0	0	0	0	0	0	0	0	0	1



Ring-structured hub network

Y_{ij}	**1**	**6**	**7**	**8**	**10**
1	0	0	1	1	0
6	0	0	0	1	1
7	1	0	0	0	1
8	1	1	0	0	0
10	0	1	1	0	0

Figure 3: Solution matrix

4.2.2. Parameter Tuning Of the Applied NSGA-II

The appropriate design of the parameters, highly affects the efficiency of the algorithms. There are many techniques to design statistically an experimental investigation. The response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The method was introduced by Box and Wilson (1951). The main idea of the RSM is to use a sequence of designing experiments to obtain an optimal response. The parameters of the applied NSGA-II algorithm are tuned by The RSM method by Design Expert 8 software.

4.2.3. Quantitative Metrics of Evaluating the Algorithm Performance

In this paper, to validate the performance of the algorithm, the following three metrics are taken into account;

- *Number of non-dominated solutions*: By applying this metric, the number of candidate solutions on the near-optimal Pareto can be calculated. The higher number of non-dominated solutions, the better the algorithm.
- *Spacing metric*: This metric calculates the uniformity of the spread of the non-dominated solutions set. The algorithm will work better if the mentioned metric gets lower values.
- *Diversity metric*: This metric calculates the spread of the solution set for the algorithm. The algorithm will work better if the mentioned metric gets higher values.

5. Numerical experiments

In this section, the proposed model is solved using small and large size test problems generated from Turkish dataset that was presented by Tan and Kara (2007). In order to validate the model and the performance of the applied meta-heuristic algorithm, the mentioned test problems are solved using both exact method (ε-constraint method) and multi-objective non-dominated sorting genetic algorithm-II (NSGA-II) which its parameters are tuned by RSM method. GAMS23.5 software is used for the exact method and MATLAB software for the applied meta-heuristic method on a system with Intel® Core TM Duo T9300 processor (2.50 GHz) with 2 GB of RAM operating under the system windows. Then by changing some parameters of the model, a sensitivity analysis is also provided to illustrate the validity of the model.

5.1. Computing the Cover Constraint

Equation (15) explains the calculation of the cover radius to apply it in the model (Sahraeian & Korani, 2010). By using the cost table, the minimum number in each column is obtained (without zeros). Also by choosing the maximum number among the minimum numbers of the columns, cover radius is found.

$$\theta = max_i \left(min_j C_{ij} \right) \tag{15}$$

5.2. Computational Results

In this section, the designed test problems are solved with both exact and meta-heuristic methods mentioned in Section 4. The results are given comparatively in Table 1. As it is explicit from the results of Table 1, for small instances, optimal Pareto solutions are available but for large scale problems, it is needed to use NSGA-II algorithm to find near optimal Pareto frontiers. Using equation (16), the measure gap can be computed to compare the performance of the proposed solution approaches.

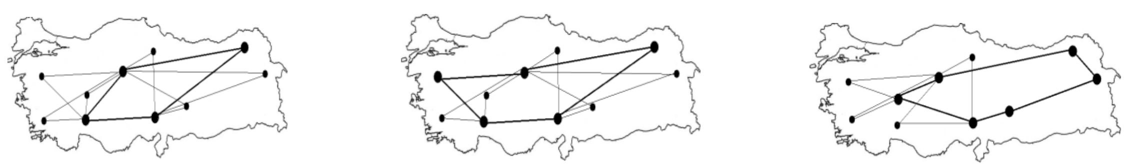
$$Gap\% = \frac{obj_{heuristic} - obj_{optimal}}{obj_{optimal}} \times 100 \tag{16}$$

5.3. Sensitivity Analysis

In this section, the model is solved in various instances to determine the sensitivity of solutions on various values of the parameters. The data used to solve the following cases are similar to the data which are discussed in the previous section. At first, the resulted configuration of a special small test problem is illustrated to show the ring structure of the hub network and give intuitive insight. As it is shown, Figures 4 and 5 are the illustration of the two optimal-Pareto solutions which are the ring hub networks of the Turkish dataset with 10 nodes and 4, 5 and 6 hubs. Moreover, Table 2 shows the corresponding values of the objective functions for the mentioned two optimal Pareto solutions.

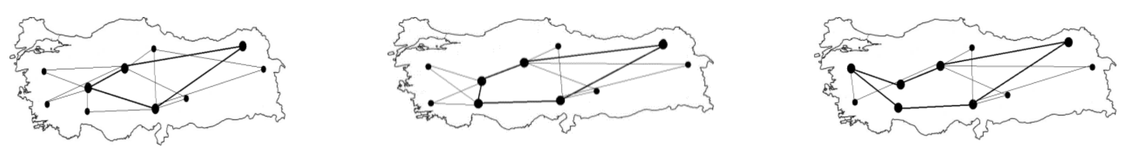
Table 1: Comparison of the ε-constraint results with NSGA-II (*r*=2)

# of nodes (*N*)	# of hubs (*p*)	ε-constraint		NSGA-II		Gap		CPU	
		$\bar{Z}_1$	$\bar{Z}_2$	$\bar{Z}_1$	$\bar{Z}_2$	Z_1	Z_2	ε-constraint	NSGA-II
10	4	1885.07	12598.3	1885.07	12598.3	0.00	0.00	25	32.814
	5	2319.74	11930.8	2319.74	11930.8	0.00	0.00	29	34.905
	6	2929.23	11259.1	2929.23	11259.1	0.00	0.00	34	38.003
15	4	1945.52	17816.09	1946.3	17825	0.04	0.05	157	74.485
	5	2440.03	16657.14	2442.23	16668.8	0.09	0.07	213	96.655
	6	2870.1	16189.83	2873.07	16204.4	0.10	0.09	270	113.996
20	4	22194.17	1766.69	22220.8	1769.87	0.12	0.18	962	176.757
	5	2272.49	20695.61	2277.95	20757.7	0.24	0.30	1204	184.823
	6	2626.81	20384.76	2635.48	20466.3	0.33	0.40	1460	200.102
25	4	1523.65	24809.84	1532.49	24958.7	0.58	0.60	3305	257.003
	5	1978.40	22995.63	1990.47	23133.6	0.61	0.60	3764	299.677
	6	2385.18	23840.13	2406.41	24023.7	0.89	0.77	4010	377.007
40	4	-	-	1723.32	52303.6	-	-	-	472.034
	5	-	-	2073.65	48080.3	-	-	-	521.030
	6	-	-	2424.45	45663.6	-	-	-	573.658
81	4	-	-	1741.26	106633	-	-	-	641.754
	5	-	-	2082.4	101634	-	-	-	675.340
	6	-	-	2424.45	97431.1	-	-	-	722.098



(a) (b) (c)

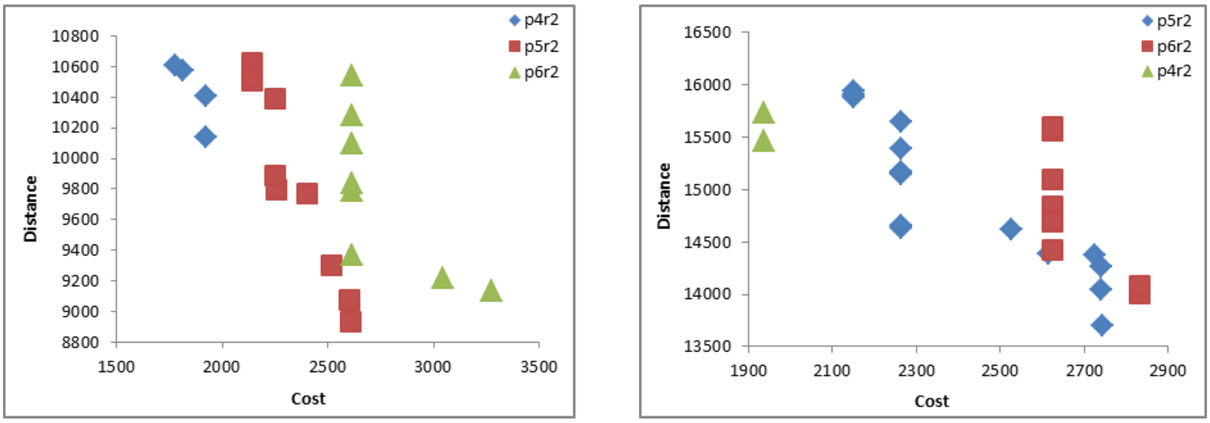
Figure 3: (optimal Pareto solution1) ring-structured hub network of a Turkish dataset with 10 nodes and (a) 4 hubs, (b) 5 hubs and (c) 6 hubs (*r*=2)



(a) (b) (c)

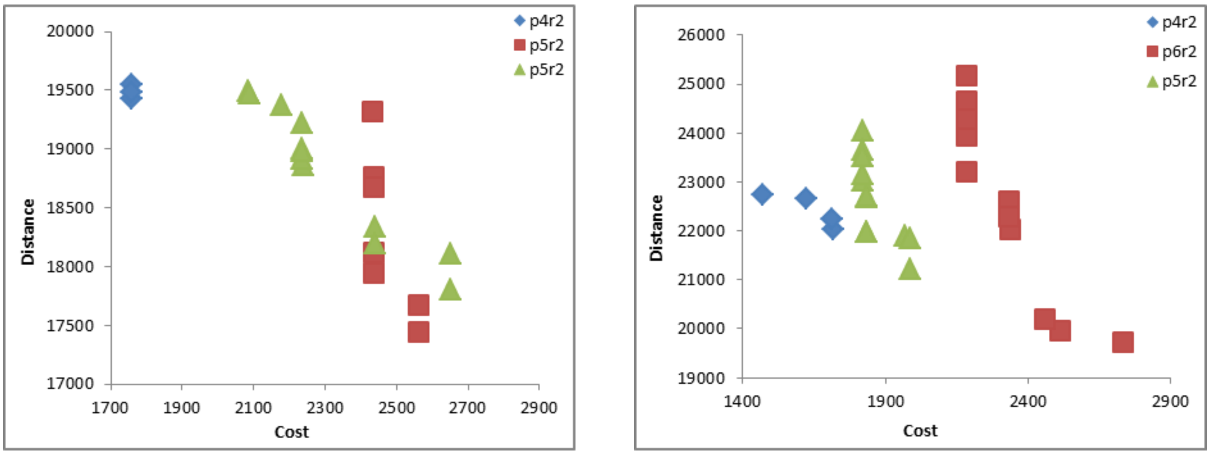
Figure 5: (Optimal-Pareto solution 2) ring-structured hub network of a Turkish dataset with 10 nodes and (a) 4 hubs, (b) 5 hubs and (c) 6 hubs (*r*=2)

Figures 6 to 8 show the near-optimal Pareto solutions of the proposed model with different parameters. As it is obvious from these figures and Table 1, by increasing the total number of nodes and the total number of the established hubs, the installation cost of hubs and arcs and also the total distance will increase.



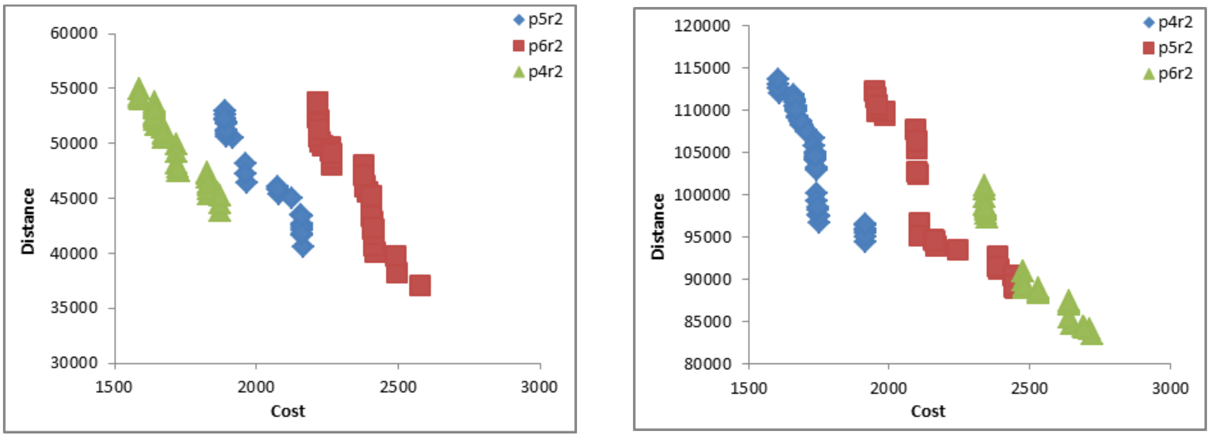
(a) (b)

Figure 6: Near-optimal Pareto solution of the proposed model with (a) 10 nodes, (b) 15 nodes and 4, 5, and 6 hubs *(r=2)*



(a) (b)

Figure 7: Near-optimal Pareto solution of the proposed model with (a) 20 nodes, (b) 25 nodes and 4, 5, and 6 hubs *(r=2)*



(a) (b)

Figure 8: Near-optimal Pareto solution of the proposed model with (a) 40 nodes, (b) 81 nodes and 4, 5, and 6 hubs *(r=2)*

Table 2 reports the performance evaluation metrics of the applied algorithm (i.e. number of non-dominated Pareto solutions, spacing and diversity metrics). As it is obvious from these Tables, spacing metric has a non-descending trend with the increase in the number of nodes and also number of hubs. In diversity metric, by not considering its fluctuations, an ascending trend can be inferred from the results when the number of nodes and hubs increase.

Table 2: Resulted metrics for evaluating the algorithm performance

P=4

No. of nodes	No. of non-dominated solutions	Diversity	Spacing
10	3	34.564	0.1032
15	2	23.065	0.2005
20	4	23.345	0.3881
25	30	195.290	0.8544
40	50	735.967	0.8015
81	76	1115.286	0.8333

P=5

No. of nodes	No. of non-dominated solutions	Diversity	Spacing
10	8	104.956	0.5101
15	11	150.131	0.4180
20	23	162.280	0.7587
25	26	259.948	0.8643
40	52	790.429	0.8190
81	49	949.002	0.6832

P=6

No. of nodes	No. of non-dominated solutions	Diversity	Spacing
10	17	184.834	0.4426
15	16	206.710	0.6917
20	16	176.684	0.5864
25	22	271.335	0.9063
40	51	866.091	0.8258
81	44	1066.233	0.8250

6. Conclusion

This paper presents a new multi-objective mathematical model for the multiple-allocation hub covering location problem with a ring-structured hub network. Due to the computational complexity of the presented NP-hard model and achieving the near-optimal Pareto solutions, a multi-objective non-dominated sorting genetic algorithm (NSGA-II) is used. To tune its parameters, a response surface methodology (RSM) is used. Then, computational trials for test problems, including small and large -sized instances generated from the Turkish dataset, are solved by an exact method (i.e., ε-constraint method) for small instances and the NSGA-II for large instances. The performance of the NSGA-II is evaluated by comparing the resulted Pareto solutions of both methods. The satisfying results show that the algorithm ensures good performance. Moreover, a sensitivity analysis is conducted to determine the sensitivity of solutions on various values of the parameters. Some extensions of this research as a future study might be of interest. The routing of the traffic refer to the way in which the flows between nodes of the network are routed through the ring of hubs and the ring capacities are not considered in this study and could be valuable future research subjects.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A Parallel Kalman Filter for Estimation of Human Body Segment Orientation Using Wearable IMMU

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Over the past decade, wearable sensor technology has gained the huge interest in the context of physical medicine and rehabilitation. This is mainly due to the tremendous benefits that could be associated with long-term monitoring of individuals in the home and community settings [1,2]. Inertial (i.e. accelerometers and gyroscopes) and magnetic sensors do not have in-the-lab measurement limitations and thus are ideal for wearable motion capture systems [3]. In many biomechanical analyses, one of the main physical quantities of interest is an orientation of each body segments [4-6]. Thus, this paper deals with 3D orientation estimation using 9-axis IMMU (inertial and magnetic measurement unit) signals.

In the IMMU-based orientation estimation, the accelerometer and magnetometer provide the vertical and horizontal references through the gravity acceleration and geomagnetic field, respectively. However, the accelerometer output is the sum of the gravity acceleration and external acceleration, and the magnetometer output is the sum of the geomagnetic field and the magnetic disturbance [7]. Note that the two components of each sensor output are not distinguishable unless the orientation is known - it is the goal to estimate. Due to this problem, most orientation estimation algorithms assume a desirable but unrealistic condition (i.e., slow motion and magnetically homogeneous conditions). Some algorithms adopt compensation mechanisms for external acceleration and/or magnetic disturbance. For example, in [3] and [6],the measurement noise covariance matrix of the accelerometer and/or magnetometer are changed depending on the kinematic and/or magnetic conditions so that weight of accelerometer and/or magnetometer signals are adjusted compared to weight of gyro signals.

The proposed parallel Kalman filter (KF) is composed of two separate KFs as the 3D orientation in the proposed KF is divided into two: attitude and heading. Then, one KF estimates the attitude and external acceleration using the accelerometer and gyro signals and the other KF estimates the heading and magnetic disturbance using the magnetometer and gyro signals (see Fig. 1). The proposed KF completely decouples the effect of magnetic disturbance from the attitude estimation due to its parallel KF configuration. Furthermore, the novelty of the proposed method is in that the external acceleration and disturbance are designated as state vectors in KF structure.

Experimental tests were conducted to verify performance of the proposed algorithm in various conditions: slow and fast motion conditions and magnetically homogeneous and disturbed conditions. It is shown in Table 1 that the parallel KF is useful to obtain accurate 3D orientation estimations in dynamic and magnetic environments. Due to its high accuracy even in undesirable operating conditions, the proposed algorithm can readily be implemented in miniature wearable sensors on a subject’s body segments, realizing a truly portable and ubiquitous human motion capture system.

Table 1. Comparison of estimation accuracies (root mean squared errors, unit: degree)

	Roll	Pitch	Yaw	Average
Test 1[a]	0.8	1.2	2.1	1.37
Test 2[b]	1.1	1.3	3.2	1.87
Test 3[c]	1.6	1.5	2.4	1.83
Test 4[d]	2.1	2.5	3.8	2.80

[a] slow and magnetically homogeneous condition; [b] slow and magnetically disturbed condition; [c] fast and magnetically homogeneous condition; [d] fast and magnetically disturbed condition

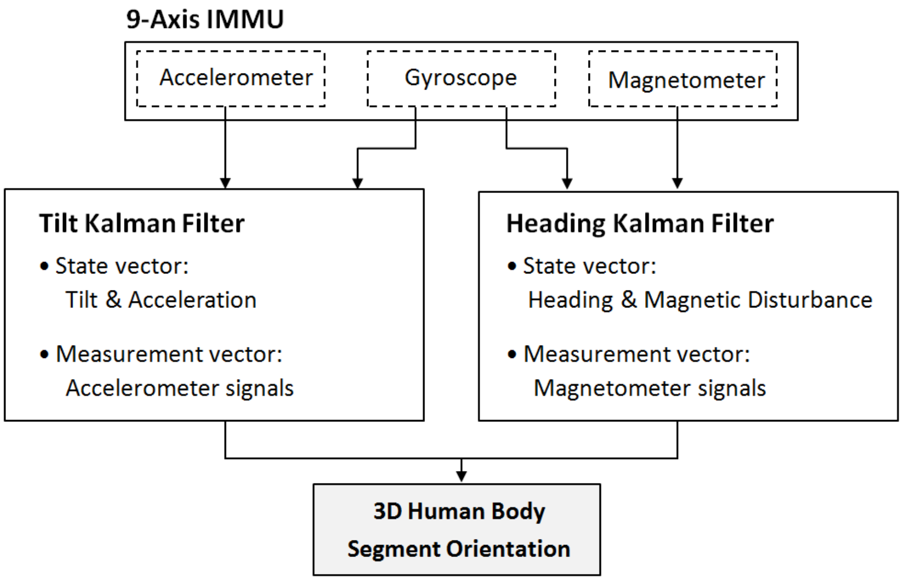

Figure 1. Flow chart of the proposed parallel Kalman filter based on 9-axis IMMU.

Acknowledgements
This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (NRF-2015R1C1A1A02036373).

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Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Understanding Facebook Usage of Undergraduate Students in Turkey

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Abstract

The aim of this study is to examine the Facebook usage behavior of undergraduate students in Turkey. We are interested in the effect of factors related to Facebook, such as continuous intention to use Facebook and the time spent on Facebook. Entertainment, information seeking, escapism, passing time, and social interaction, were selected as the motivating factors because of their potential effect in explaining the motivation of using Facebook. A survey methodology was used in this study to gather data. A total of 341 questionnaires was collected. The results reveal that entertainment is a significant determinant of both continuance intention to use Facebook and the time spent on Facebook. Moreover, information seeking is another predictor of continuance intention to use Facebook, whereas escapism is also a determinant of the time spent on Facebook. More importantly, the mean difference between female and male students is found to be insignificant in terms of continuance intention to use and the time spent.

Keywords
Social networking sites, uses and gratifications, continuance intention to use Facebook, time spent on Facebook

1. Introduction

Facebook is the most popular social networking site that was founded on February 4, 2004 by Mark Zuckerberg and his friends from the University of Harvard. Facebook is used to share important things to others, express themselves to others, get news about the things happening in the world, and keep in touch with family and friends (Facebook Newsroom, 2014). Worldwide, the numbers of daily and monthly active users of Facebook are 757 million and 1.23 billion, respectively, as of December, 2013 and the daily users of Facebook outside the United States and Canada are around 81% of the total users (Facebook Investor Relations, 2014).

The aim of this study is to examine the Facebook usage behavior of undergraduate students in Turkey. We are interested mainly on the effect of factors related to Facebook use on continuance intention to use Facebook and the time spent on Facebook. In the literature, Uses and Gratification Theory (UGT) analyzes the media usage behavior of individuals. It seeks an answer to "What do people do with media?" instead of "What do the media do to people?" (Katz, 1959). Therefore, this theory focuses on how and why people depend on the social media and what social and psychological needs of users are being met (Katz, Blumler, & Gurevitch, 1974; Katz, Gurevitch, & Haas, 1973).

In this study, entertainment, information seeking, escapism, passing time, and social interaction are selected as the motivating factors because of their potential effect in explaining the motivation of using Facebook. In the literature, several studies have already explored the above motives for using Facebook (Sheldon 2008, Joinson 2008, Sharifah Sofiah et al., 2011, Dhaha and Igale 2013). Sheldon (2008) investigated the students' motives for using the Facebook. Explorative factor analysis was conducted and the results reveal that relationship maintenance, passing time, virtual community, entertainment, coolness, and companionship are the motives for students to use Facebook. He also investigated what gratifications of Facebook use play a role in predicting attitudinal and behavioral outcomes such as the number of hours spent on Facebook and the number of logs into the Facebook account. According to the results, the number of hours students spent on Facebook was predicted by relationship maintenance and passing time, the number of logs into the account was determined by relationship maintenance, passing time, and entertainment. Joinson (2008) has explored the uses and gratifications of Facebook in which seven motives for using Facebook are extracted: social connection, shared identities, photographs, content, social investigation, social network surfing, and status updates. He also examined the effects of these factors, gender, age, and occupation on predicting Facebook use (the frequency of visits to the site and the time spent on the site during an average week) in his study. He conducted two different multiple regression analyses to predict the frequency of Facebook use and the amount of time spent on Facebook. The results show that gender, photographs, social investigation, and status updates have a significant effect on predicting the frequency of visits to Facebook and age and content gratification are significantly associated with the actual number of hours spent online. Sharifah Sofiah et al. (2011) conducted a study that questions the motives caused Facebook addiction among female university students in Malaysia. They use five factors (social interaction, passing time, entertainment, companionship, and communication were the main reasons) identified in the literature to understand the users' motives for Facebook and explore the addiction level among female students. In this study, regression analysis was run to test the relationship between variables. The results of the analysis exert that there is a significant relationship between each motive and Facebook addiction, and passing time has the strongest influence on the addiction of Facebook. Dhaha and Igale (2013) have investigated the motives behind why Somali youths use Facebook. In this study, an exploratory factor analysis was conducted and six factors have been yielded: virtual companionship escape, interpersonal habitual entertainment, self-description of own country, information-seeking, self-expression, and passing time. These six factors were also questioned whether they have a significant effect on predicting the time spent on Facebook. For this, they conducted a regression analysis to predict the time spent on Facebook daily. According to the results of the analysis, virtual companionship escape, interpersonal habitual entertainment, and self-description of own country are found as the prevalent motives of using Facebook. There are also other studies that investigate the effects of motivational factors on continuance intention to use Facebook. Shi et al. (2010) analyzed the effects of disconfirmation of maintaining offline contacts, disconfirmation of meeting new people, disconfirmation of information seeking, disconfirmation of entertainment on the continuance intention of Facebook through satisfaction. The results of their study reveal that disconfirmation of maintaining offline contacts, disconfirmation of information seeking, and disconfirmation of entertainment affects continuance intention to use Facebook through satisfaction. In the study of Basak and Calisir (2015), the effects of entertainment, self-expression, information seeking, and status seeking on continuance intention to use Facebook through satisfaction and attitude were investigated, and it is found that entertainment and status seeking are the motivational factors that affect individuals' continuance intention to use Facebook.

2. Research Model and Hypotheses

2.1. Entertainment

Entertainment can be defined as the extent to which the use of a particular medium is entertaining and exciting to its users (Eighmey & Mccord, 1998). People spend their leisure time and have fun while interacting with a particular medium; thus, media entertainment fulfills the needs for enjoyment, pleasure, and fun through this interaction (Papacharissi & Rubin, 2000). Special and Li-Barber (2012) assert that users can be entertained through Facebook in various ways; for example, surfing on a friend's page, seeing photos, or learning what their friends are doing by reading through newsfeed on Facebook, etc. The more entertained users are more likely to continue to use Facebook and spend time on Facebook. Therefore, we hypothesize as follows:

H1: Entertainment has a positive effect on continuance intention to use Facebook
H2: Entertainment has a positive effect on time spent on Facebook

2.2. Information seeking

Information seeking refers to the extent to which useful and helpful information can be obtained from the media. Users may surf on Facebook to gather information about the things that they are interested in. They can acquire a vast amount of information in an inexpensive way by viewing the posts that are shared by the user whom they have befriended, the groups that they join, or pages which they follow. Kim et al. (2011) point out that surfing on the SNSs is a way of learning new things, making a research, and collecting useful information from the interactions with friends. Owing to Facebook, users may find out more information about interesting things such as hot topics, new trends, interesting news via shared posts, and discussions on Facebook (Shi et al., 2010).

H3: Information seeking has a positive effect on continuous intention to use Facebook
H4: Information seeking has a positive effect on time spent on Facebook

2.3. Escapism

Escapism refers to the extent to which the use of particular medium makes users to get away from problems and pressures in their lives (Hirschman, 1983). Users may willingly show escapism behavior to be relieved from the burdens of daily life toward using the media, and they may expect that the media take them away from unpleasant things (Hirschman, 1983). "To leave the reality in which they live in a cognitive and emotional way" can be an influential motive for individuals to participate in virtual communities (Henning & Vorderer, 2001). Individuals perform several internet activities related to escapism behavior to forget responsibilities and concerns of a daily life for a while. Surfing the news, blogs, SNSs, and forums can be given as examples to these activities (Abrantes, Seabra, Lages, & Jayawardhena, 2013). Individuals who are engaged in behaviors related to escapism are expected to complete their tasks slowly and to feel less bored by the responsibilities of the life when using a particular medium (Verhagen, Feldberg, van den Hooff, Meents, & Merikivi, 2012).

H5: Escapism has a positive effect on continuance intention to use Facebook
H6: Escapism has a positive effect on time spent on Facebook

2.4. Passing time

Sheldon (2008) exerts that students use Facebook to occupy their time when they are bored. In the study of Special & Li-Barber (2012), passing time has been found as the second strongest motivator for using Facebook. It has been concluded that users of Facebook derive more satisfaction from relationship maintenance, passing time, and entertainment. Papacharissi & Mendelson (2010) have found that users spend time on Facebook to pass the time away when they have a feeling of boredom. According to Sharifah Sofiah et al. (2011), Facebook is a place for passing time for getting away from the feeling of boredom, and this behavior is related to the idea of being socialized with friends online. Valentine (2011) has pointed out that users spend time on Facebook when they have nothing to do better.

H7: Passing time has a positive effect on continuance intention to use Facebook
H8: Passing time has a positive effect on time spent on Facebook

2.5. Social interaction

SNSs enable individuals to perform interaction with each other by using communication tools such as texts, videos, or photos to maintain and sustain their relationships. The members of these virtual platforms are easily getting in touch and making social ties with other users, and they express themselves by sharing their own thoughts and opinions (Lin & Lu, 2011). Facebook is basically used to carry out a relationship between distant friends or family, to meet new people, or to learn what friends are doing by building communication and network. Owing to the communication tools of Facebook, the social interaction gratification of users is more likely to be increased, and this gratification leads to increased time spent on Facebook and increased frequency of use (Joinson, 2008). In the study of Sheldon (2008), it is revealed that students use Facebook to maintain relationships with people they know owing to the behaviors such as sending a message to a friend, posting a message on their friend's wall, staying in touch with a friend or getting in touch with someone who is difficult to reach.

H9: Social interaction has a positive effect on continuance intention to use Facebook
H10: Social interaction has a positive effect on time spent on Facebook

In light of the hypotheses discussed above, the research model tested in this study is shown in Fig. 1.

3. Methodology

A survey methodology was used in this study to gather data. The target population is the undergraduate students using Facebook. The questionnaire was formed by two main parts. The first part consisted of demographic questions designed to solicit information about age, gender, Facebook membership, internet use in a day, social networking sites use in a day, Facebook use in a day. A total of 341 questionnaires was collected. The 46.29% of respondents were female, and the average age of respondents was 21.17 years. The summary of demographic profiles of the participants is given in Table 1.

The second part consisted of the items measuring continuance intention (Bhattacherjee, 2001; Mathieson, 1991), entertainment (Ducoffe, 1996), information-seeking (Korgaonkar & Wolin, 1999), escapism (Korgaonkar & Wolin, 1999), passing time (Papacharissi, 2002), and social-interaction (Papacharissi, 2002; Papacharissi & Rubin, 2000). The items for the constructs can be seen in Table 2. The items were modified to make them relevant to Facebook use. A five-point Likert-scale type was used to measure the items. In a five-point Likert-type scale, one represents "strongly disagree" and five represents "strongly agree".

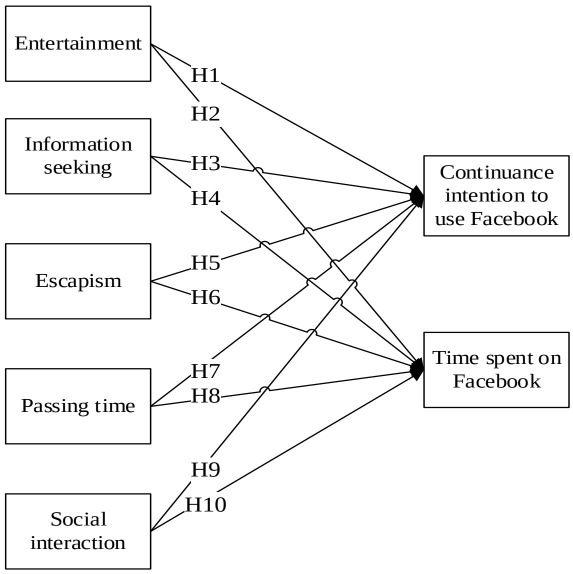

Figure 1. Research Model

Table 1: Demographic profiles of the respondents.

Age (years)		
Max: 26	Min: 18	Average: 21.17
Gender (%)		
Female: 46.29	Male: 53.71	
Facebook membership (years)		
Max: 9	Min: 0,5	Average: 5.23
Internet use in a day (hour)		
Max: 14	Min: 0.5	Average: 3.77
SNSs use in a day (hour)		
Max: 9	Min: 0.25	Average: 2.00
Facebook use in a day (hour)		
Max: 8	Min: 0.25	Average: 1.20

Table 2: Construct, code, and the items.

Construct	Code	Items
Continuance intention	CON01	I would use Facebook rather than other social network sites
	CON02	My intention would be to use Facebook rather than other social network sites
	CON03	If I could, I would like to continue my usage.
Entertainment	ENT01	I use Facebook because it is entertaining
	ENT02	I use Facebook because it is enjoyable
	ENT03	I use Facebook because it is pleasing
	ENT04	I use Facebook because it is fun to use
	ENT05	I use Facebook because it is exciting
Escapism	ESC01	I use Facebook so I can escape from reality
	ESC02	I use Facebook so I can get away from what I am doing
	ESC03	I use Facebook so I can forget about work/school
	ESC04	I use Facebook because it takes me into another world
Passing time	PAS01	I use Facebook because it passes time away when bored
	PAS02	I use Facebook when I have nothing better to do
	PAS03	I use Facebook to occupy my time
Information-seeking	INF01	I use Facebook because it gives quick and easy access to large amount of information
	INF02	I use Facebook because I learn a lot from using it
	INF03	I use Facebook so I can learn about things happening in the world.
	INF04	I use Facebook because information obtained from it is useful
	INF05	I use Facebook because it makes acquiring information inexpensive
Social interaction	SOC01*	I use Facebook to meet new people
	SOC02*	I use Facebook because I wonder what other people said
	SOC03	I use Facebook to communicate with distant friends
	SOC04	I use Facebook to keep in touch with friends and family

4. Results

The Cronbach's alpha statistic is used to measure internal consistency reliability in each factor. Robinson, Shaver, and Wrightsman (1991) suggest that 0.70 is accepted as a lower limit for the value of Cronbach's alpha, and it is used to diagnose that a factor has a good internal consistency. The initial results of the reliability analysis show that all of the variables except SOC have Cronbach's alpha over 0.70. As a SOC does not meet the minimum limit of Cronbach's alpha, it is essential to eliminate some items in this variable to have a better internal consistency. According to the results of the reliability analysis, SOC01 and SOC02 are excluded from the model one-by-one. By excluding these items, Cronbach's alpha of SOC increases to 0.70. The Cronbach's alpha values of the constructs can be seen in Table 3.

The regression analysis is conducted to test the relationships between variables. R2 value of 0.239 implies that only 23.9% of the total variance of the continuance intention to use Facebook is explained, whereas R2 of 0.092 implies that only 9.2 % of the total variance of the time spent on Facebook is explained.

Table 3: Cronbach's alpha values of the variables.

Variable	Cronbach's alpha of untrimmed constructs	Cronbach's alpha of the revised constructs
CON	0.735	-
ENT	0.830	-
INF	0.868	-
ESC	0.827	-
PAS	0.772	-
SOC	0.501	0.701

The results reveal that entertainment is a significant determinant of both continuance intention to use Facebook and the time spent on Facebook. Moreover, information seeking is another predictor of continuance intention to use Facebook, whereas escapism is also an estimator of the time spent on Facebook. The standardized coefficient, β, gives the degree of importance of independent variables in explaining the dependent variable implying that the effect of information seeking on both continuance intention to use Facebook and the time spent on Facebook is high compared to the effect of entertainment and escapism. On the other hand, both passing time and social interaction are found to be insignificant in explaining continuance intention to use Facebook and the time spent on Facebook. The results of the regression analyses are given in Table 4.

Table 4 : Predicting continuance intention to use Facebook and the time spent on Facebok

	Continuance intention to use Facebook			Time spent on Facebook		
	β	***t***	***Sig***	***β***	***t***	***Sig***
Entertainment	0.27	5.27	0.00	-0.076*	1.351	0.178
Information seeking	0.32	6.36	0.00	0.20	3.74	0.00
Escapism	0.33*	0.662	0.508	0.19	3.46	0.00
Passing time	-0.48*	-0.893	0.373	-0.085*	1.514	0.131
Social interaction	0.19*	-0.374	0.709	-0.027*	0.501	0.616

* insig. at $p<0.05$

A one-way ANOVA analysis was conducted to check if there is a significant difference among female and male students with regard to both continuance intention to use Facebook and the time spent on Facebook. Firstly, the assumption that whether the variances are equal was justified with a Levene Statistic of 0.709 and 0.671 and a significance value of 0.400 and 0.330 at 0.05 significance level. Secondly, the results of ANOVA show that the mean difference between female and male students in terms of continuance intention to use and the time spent on Facebook is found to be insignificant with the F value of 2.585 and a significance value of 0.109 (p<0.05) and with a F value of 2.585 and a significance value of 0.441 (p<0.05), respectively.

5. Discussion and Conclusion

The aim of this study is to examine the usage behavior of Facebook among undergraduate students in Turkey. For this, a survey methodology was used in this study to gather data. Target population was undergraduate students using Facebook. A total of 341 questionnaires was collected.

The explanation rates of continuance intention to use and the time spent on Facebook which are 0.239 and 0.092, respectively, and are low in this study compared to the other similar studies (Chen et al., 2012; Chiu et al., 2005; Kim, 2011). The results also show that the continuance intention to use Facebook is explained by information seeking and entertainment. Moreover, information seeking and escapism play a significant role in explaining the time spent on Facebook. Among them, information seeking is found to have a higher direct influence. Therefore, it may be concluded that undergraduate students mainly spend some time on Facebook to get information about the things happening in the world and keep using Facebook as a useful information channel. They also intend to continue to use Facebook as long as their needs of entertainment are met. Furthermore, the undergraduate students may surf on Facebook to forget their school responsibilities and get away from studying. That's why Facebook may become an escape point for them.

Another result of this study shows that passing time and social interaction have insignificant effects on both continuance intention to use and the time spent. It may be interpreted that undergraduate students are not solely interested in using Facebook only when they have nothing to do better. On the contrary, they perceive Facebook usage as a habit or a thing to do. Moreover, it may also be concluded that undergraduate students are not interested in the social gratifications of Facebook, and they do not need any interaction with their friends or family in an online-environment, they may prefer face-to-face communication rather than the online communication.

The findings of this study provide an understanding of the factors affecting the continuance intention to use Facebook among undergraduate students in Turkey and the time spent on Facebook by them, but we should also consider its several limitations. First, 23.9% of continuance intention to use and 9.2 % of time spent are explained in separate models. Thus, a considerable percentage of the variance remains unexplained suggesting the need for future study to explain user behaviors. Therefore, some additional factors that are important in explaining the continuance intention to use Facebook, such as relationship maintenance (Sheldon, 2008; Valentine, 2011), virtual communities (Sheldon, 2008; Valentine, 2011), and information sharing (Papacharissi & Mendelson, 2011; Smock et al., 2011) can be included in a model of further study.

Second, the effects on demographic attributes were not analyzed in this study. A similar study, including demographic characteristics, such as the extent of computer and Internet use, experience, age, and gender of the respondents may be a subject for future research.

Finally, this study may be combined with qualitative analysis to understand and interpret the continuance intention of using Facebook, because both qualitative and quantitative aspects may complement each other for further understanding.

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Risk Management in Hospital Settings: Understanding and Improving the Current Practice

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Abstract

In the healthcare industry, a large number of patients experience adverse events. To ensure patient safety, risk management has been implemented in hospitals. However, there is still a great potential to improve current risk management practices. Thus, this study aims to understand risk management practices applied in hospital settings and gives some suggestions to improve them. While a questionnaire survey was designed to understand current risk management applications, risk management literature was reviewed to understand and to improve these risk management applications. Results demonstrate that over 70 percent of practitioners and managers consider risk management as defining threats to patients while fewer agree on the ISO definition of risk. Additionally, almost half of the practitioners and managers agree with the statement that risk assessment is more important than risk mitigation. In terms of tools use, participants mostly used Failure Mode and Effect Analysis (FMEA), brainstorming and risk matrix techniques to manage risks. In light of the questionnaire results and literature review, risk management practices could be advanced by focusing on safety culture, staff involvement, safety training, risk reporting systems and risk management tools.

Keywords: Risk; risk management; patient safety; healthcare

1. Introduction

The Healthcare system is complex and dynamic. Additionally, healthcare staff is highly pressured. Therefore, patient safety is difficult to ensure (Jun, Ward, & Clarkson, 2010). It is estimated that 850000 medical errors occur annually in the UK healthcare services (P. J. Clarkson et al., 2004) and 400 patients die or seriously get injured annually as a result of these errors (Donaldson, 2002). What is more, the total number of patients experiencing adverse events in each year is estimated to be around 42500 in England and Wales (Smith, 2007) and over a million in the USA (Kohn, Corrigan, & Donaldson, 2000; Starfield, 2000). Also, a research claims that these patient safety problems are not only in the USA and UK, but also all over the world (P. J. Clarkson et al., 2004).

Since the Institute of Medicine report in 2000, healthcare organizations have been encouraged to learn from incidents, to develop a safety culture and to improve their risk management practices (Cagliano, Grimaldi, & Rafele, 2011; Sokol & Neerukonda, 2013). To achieve this, healthcare organizations have adopted engineering approaches from safety-critical industries (P. J. Clarkson et al., 2004). Risk management is one of these engineering applications that the healthcare industry has been adapted to ensure patient safety. While the initial focus on risk management was on financial issues as a result of healthcare insurance crisis in the USA, this understanding then moved to safety and quality issues (Dückers et al., 2009; Youngberg, 2011).

Risk management has been partially implemented in hospital settings because of limitations. Some researchers addressed gaps in risk management processes, such as risk identification (Simsekler, Card, Ward, & Clarkson, 2015; Simsekler, Card, Ruggeri, Ward, & Clarkson, 2015) and risk mitigation (Card, Simsekler, Clark, Ward, & Clarkson, 2014). However, there is little evidence found on the practical application of risk management and different levels understanding on that. Therefore, this study attempts to understand managers' and practitioners' perceptions and their implications, and to suggest potential improvement areas within current risk management practices.

2. Method

To understand practical and theoretical applications, this study conducted a questionnaire and reviewed risk management literature. The questionnaire was designed to analyze practitioners' and managers' understanding of risk management applications. The questionnaire was aimed to be short to overcome time constraints in healthcare. Thus, the questionnaire consisted of 10 multiple-choice questions *(Please see appendix 1 for the questionnaire template).* An online survey tool was used to set up questionnaire electronically and then, survey link was posted through LinkedIn groups (e.g. doctors, managers, risk managers and patient safety groups). The questionnaire was also conducted in person in a hospital setting. Data were collected via online (170 responses) and in-person (20 responses). Results were received from a variety of countries, namely USA (68), UK (42) and other countries (80). Then, collected data were categorized based on respondents' positions to observe different perceptions between managers and practitioners. Finally, data were analyzed to explain and improve current risk management practices.

3. Results

The following sections of this paper highlight questionnaire results. The results are divided into three sections: understanding of risk and risk management, risk management strategy and use of risk management tools.

Understanding of risk and risk management

Figure 1a and 1b demonstrate participants' results of the risk and risk management related questions. While 64 percent of the practitioners agreed (strongly agree and agree) with the ISO 31000 definition of risk, "the effect of uncertainty on objectives", 73 percent of the practitioners agreed that risk management is about identifying possible threats to patients (see in figure 1b). Practitioners confirmed a more comprehensive understanding of risk as in the ISO definition, yet still more practitioners agreed on a specific focus: "risk management is about identifying possible threats to patients". Same perception was observed among managers that they agreed on the ISO definition by 71 percent and more on the understanding of risk management by 78 percent.

After analyzing data based on respondents' location, it was recognized that there is a contrast between the US and UK results. To give more detail, UK practitioners agreed with 100 percent on the risk management definition more than UK managers did (78 percent). However, US trend was similar to the overall results. Managers agreed (95 percent) with the statement more than practitioners did (65 percent).

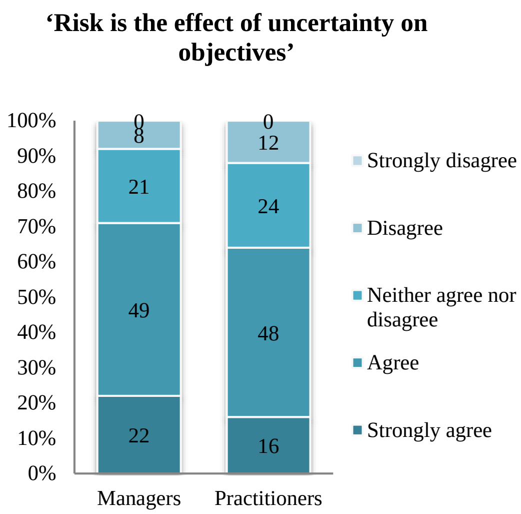

Figure 1a: Risk definition

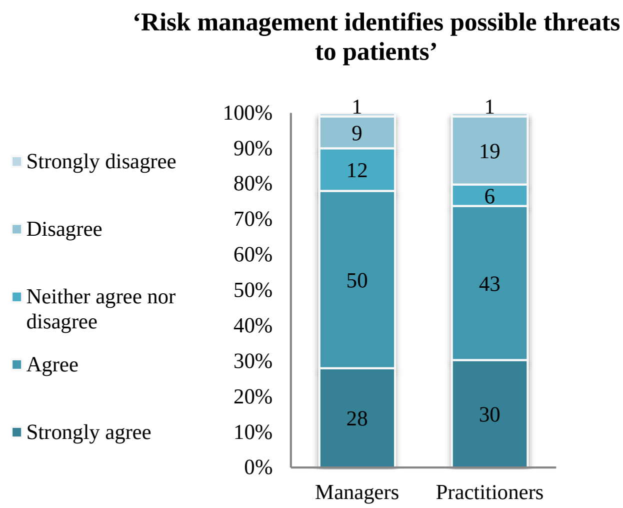

Figure 1b Risk management definition

Risk management strategy

A following question was asked: "to what extend do you agree that risk assessment is more important than risk mitigation?" to understand respondents' priority. While 47 percent of practitioners considered risk assessment as being more important than risk mitigation, 44 percent of managers agreed with the same statement. Although it is arguable that which of these should be a priority, risk management priority should be more likely to reduce risks. When results were compared based on locations, again similar responses received from different countries except UK managers and practitioners agreeing slightly more. Figure 2 below illustrates the overall responses to the given statement.

Figure 2 Risk management strategy

Use of the risk management techniques

This study also asked respondents which techniques they use for risk management applications. Results revealed that Failure Mode Effect Analysis (FMEA) was the most commonly used tool. Then, the risk matrix and brainstorming were used (see figure 3). Most importantly, results found that practitioners rarely use tools, except brainstorming and what-if techniques. However, it should be noted that using a large number of tools does not necessarily mean a good practice of risk management. Risk management tools should be used when it is necessary and where it is proper.

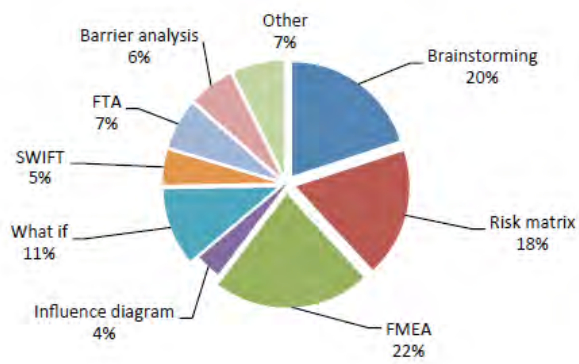

Figure 3 Risk assessment techniques used by respondents

4. Discussion

There was slight difference on a general understanding of risk and risk management between managers and practitioners. Also, it was found that healthcare staff has a priority on risk assessment rather than risk mitigation. This may be as a result of external authorities encouragement on risk assessment. Therefore, a common understanding of *how many risks assessed that much better risk management* could have been developed among healthcare staff. However, the ideal risk assessment is to mitigate risks. Hence, balancing these two should be aimed to achieve effective risk management practices. Not surprisingly, managers are more likely to use risk management techniques than practitioners, which means that front line staff is not really involved in the risk management practices. Within these tools, FMEA is the most commonly used technique. This can be explained with the development of Healthcare Failure Mode and Effect Analysis (HFMEA) by the Department of Veterans Affairs (DeRosier, Stalhandske, Bagian, & Nudell, 2002) and an enormous number of publications available in the literature (Lu, Teng, Zhou, Wen, & Bi, 2013; Manger, Paxton, Pawlicki, & Kim, 2015; Perks, Stanic, Stern, & et al., 2012; Shebl, Franklin, & Barber, 2012). When results are analyzed based on respondent locations, it has seen that UK respondents demonstrate different patterns than other countries. Different results among countries could be explained by different healthcare systems and by national authorities different level of influences on healthcare organizations.

In order to improve risk management practices, some suggestions can be given such as developing safety culture (Al-Assaf, Bumpus, Carter, & Dixon, 2003), encouraging staff involvement into risk management practices (Khatri, Brown, & Hicks, 2009), providing safety training (Mackert, Ball, & Lopez, 2011) and encouraging use of risk management reporting systems and tools.

While safety culture is a key point to encourage all healthcare staff involvement in risk management, blaming is the major handicap to implement that (P. J. Clarkson et al., 2004; Muralidhar, Taneja, & Ramesh, 2012). Healthcare staff should not be afraid of making errors and team members should recover each other's errors when they occur. This understanding is well established in the aviation industry. Cabin crew make many mistakes during flights, but anyone who realizes the mistake, solves the problem (Firth-Cozens, 2001). So, crew teams prevent mistakes before they lead to adverse events. It should be also noted that while poor team work increases the number of errors, good teams reduce the errors by helping each other and correcting each other's mistakes (Lester & Tritter, 2001; Wiegmann, ElBardissi, Dearani, Daly, & Sundt, 2007).

Ensuring safety training is also an essential factor that could improve risk management practice, especially for practitioners (Mackert et al., 2011). A research asked 40 practitioners whether or not they have been trained on risk management or patient safety and results revealed that none were trained (Arfanis & Smith, 2012). However, all practitioners are expected to register risks in their local risk register systems. Therefore, healthcare organizations should provide training to healthcare staff to support their role in the risk management practice. Also, external authorities should create safety training regulations to encourage healthcare organizations to provide effective training.

Reporting systems of the incidents or risks have also potential to improve current practice (Barach & Small, 2000). Incident reporting is one of the main sources to define risk. However, it is estimated that only between 22-83 percent of incidents are reported (Parkes, Pyer, Wray, & Taylor, 2014; Pietro, 2000). Since the gap between the estimated incident reports is really high, it already implies that there is a problem in the reporting culture. Therefore, effective reporting should be encouraged to improve risk management practices by feeding risk management with lessons learnt from incident experiences. However, it should be stated that a large number of insufficiently reported incidents cannot contribute to the risk management process. A low rate of reporting is also a problem as well as the high rate of reporting, which hides problems to be solved (Macrae, 2008). Therefore a more effective balance should be achieved between reporting too many and too few to management risks.

There are a variety of risk management tools are to prevent incidents, to mitigate risks, and to ensure safety. However, this study found that practitioners do not have the tendency to use risk assessment tools. Some underlying reasons for this lack of implementation can be explained by healthcare staff time allowance, staff knowledge levels and staff fears of being exposed for their mistakes (Carroll, 2009; Eidesen, Sollid, & Aven, 2009; Spedding & Rose, 2008). Another point is that hospitals have a static system that uses the same risk assessment tool for all types of risks and with all processes, which sometimes is not adequate. Still, healthcare organizations benefit from risk management tools through the proper use and right selection of the risk assessment techniques (e.g. FMEA, FTA, ETA, and HRA) by the involvement of staff at all levels.

Some limitations of this research should be also mentioned. Characteristics of the risk management practice may differ from one country to another. Different hospital types or even different hospital wards may have different levels of risk management understanding. Therefore, the same risk management practices may not be as effective. Additionally, questionnaires may be biased by the fact that respondents could have tried to provide correct answers rather than revealing their real experiences and knowledge. However, this study gives an overview of the risk management practices by highlighting general issues.

5. Conclusion

Risk management is a way to ensure patient safety by preventing adverse events, but current risk management practice has not properly implemented yet. Some of the problems observed with this study can be given: having different perceptions of risk management, healthcare staff giving a priority on risk assessment rather than risk mitigation and lack of risk management tools use especially by practitioners. However, there is a great potential to improve risk management practices. Some interventions could be suggested such as safety culture, staff training and the proper use of risk management tools. Further research can be conducted to implement suggested interventions in a hospital setting.

Acknowledgments

This paper presents independent research funded by the National Institute for Health Research (NIHR). The views expressed are those of the authors and not necessarily of the NHS, the NIHR or Department of Health.

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Appendix 1

This questionnaire aims to understand and develop healthcare risk management practices and strategies in hospital settings.

Your answers will help to understand the current situation of risk management in hospital environment.

Position in the hospital/ country:

To what extent to you agree with the following statements:

1) Risk is the effect of uncertainty on objectives

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

2) Risk management is about identifying possible threats to patients

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

3) Risk management involves ensuring that the hospital works efficiently

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

4) Risk management aims to ensure that the healthcare provided is good value for money.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

5) Identifying a large number of risks makes the system safer and better.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

6) Risk assessment is more important than risk mitigation.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

7) Risk is efficiently managed in my organisation.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Could you please answer the following questions?

8) When thinking about risk, my primary focus is on the needs of:

☐ An individual patient ☐ A group of patients (e.g. ward) ☐ The hospital as a whole ☐ The local community ☐ The NHS ☐ Other

If other, could you please specify?

9) Which technique do you use for risk management

- ☐ Brainstorming
- ☐ FMEA
- ☐ What If
- ☐ FTA
- ☐ Likelihood Impact Grid (Risk Matrix)
- ☐ Influence Diagram
- ☐ SWIFT
- ☐ Barrier Analysis

10) When tracking risks, I formally review risks at a frequency of:

- ☐ Once per day
- ☐ Once per week
- ☐ Once per month
- ☐ Once per year
- ☐ Every few days
- ☐ Every few weeks
- ☐ Every few months
- ☐ Every few years
- ☐ Other

If other, could you please specify?

Email address (Optional) :

☐ If you would like a summary of the *results*, *please* tick the box by providing *your email address*.

Thank you for participating in our questionnaire.

Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Analysis of Interactions among the Lean Implementation Barriers

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Abstract

Lean practices are implemented both in manufacturing and service companies in order to find the hidden wastes and improve continuously. However, many organizations experienced failure in lean implementation. Beside the application of appropriate lean tools and techniques, there are many other factors that affect the success of the lean implementation process. A recent literature survey by Jadhav et al. (2014) lists the barriers of lean implementation as the lack of resources to invest, lack of top management focus leadership, workers' resistance, cultural difference, lack of top management involvement (commitment and support), lack of perseverance, top management resistance, lack of communication between management and workers, quality problems with supplied material, lack of cooperation from suppliers, lack of influence over suppliers of lack of involvement of suppliers in the actual implementation. Understanding the barriers and the interactions between them can be crucial to the success of lean implementation. This paper utilizes the Interpretive Structural Modeling (ISM) methodology to determine the influences among the barriers so that we can distinguish the driving barriers, which are at the root of hierarchy, and the dependent barriers, which are at the top of the hierarchy. By analyzing the barriers, we can extract crucial barriers that hinder the lean implementation process. The analysis provides an arrangement of the barriers in a hierarchy and their categorization into driver and dependent categories. The study concludes with a discussion and the managerial implications.

Keywords

Lean implementation barriers, lean implementation, interpretive structural modeling.

1. Introduction

Most of the companies are willing to adopt lean philosophy and its principles since it eliminates the wastes within an organization in order to improve the performance. It is a total system approach to create an efficient operation and pull together the best practices and concepts (Jadhav et al., 2014). It provides with a radical solution to the problems by handling the root causes.

The lean philosophy adopts the idea of continuous improvement, and progress in quality studies cannot be ended. Even sometimes a deliberate breakdown is made to the system in order to see what will be the consequence in case of any failure. Hence, the organizations are trying to implement lean principles which requires a dedicated change in business.

Lean principles require a maturity both in companies’ organization and operations, and in management dedication. The basic problems should be solved immediately within a firm, otherwise the lean philosophy cannot be applied. It is obvious that this is a transformation process from a traditional labor-intensive system to more efficient one. Moreover, the transformation brings some difficulties to implement the lean principles like the lack of resources to invest, lack of top management focus leadership, workers' resistance and cultural difference.

The aim of the paper is to analyze the challenges of lean implementations in order to show which challenge affects the one another in which way with a hierarchical structure. In the scope of the research, we defined lean implementation barriers via Jadhav et al. (2014) literature survey study, discussed as variables. Expert opinions are used to define the relationships among the variables, and these relationships are analyzed.

Research methodology of the study consists of literature review for the lean implementation barriers definition, conducting a questionnaire for collecting expert opinions and using Interpretive Structural Modeling (ISM) and MICMAC analysis for the relationship analysis. The reasons behind why the ISM as the selected research methodology is that it can visually generate hierarchical graphs for defined risks. Additionally, MICMAC analysis shows the dependency situation of the variables.

Main finding of the analysis highlights that the barriers have relations each other and it points out that the root cause of the barriers can be determined with a hierarchical model of barriers' relationships. The dependency of variables can be seen in a visual graphs.

In the following sections, a literature review is conducted in order to define the lean implementation barriers, the expert opinions are gathered to determine the relationship between each individual barrier couple so that it can be possible to apply the Interpretive Structural Modeling for the analysis of these variables. Sequentially, MICMAC analysis is applied to see the internal dependency situation of the barriers.

2. Literature Review

The literature review shows that most of the papers are about identifying lean elements, lean implementation benefits and strategies, influence on performance and relations (Jadhav et al., 2014). Professionals are willing to utilize lean implementations, but there are some barriers to put them into use. Jadhav et al. (2014) study focuses on a comprehensive coverage on the lean barriers. They identify twenty-four significant barriers for successful lean implementation as follows:

- Top management resistance
- Lack of top/senior management focus leadership
- Lack of top/senior management involvement (commitment and support)
- Lack of communication between management and workers
- Lack of empowerment of employees
- Workers' resistance
- Lack of perseverance
- Lack of consultants and trainers in the field
- Lack of formal training for managers
- Lack of formal training for workers
- Cultural difference
- Lack of cooperation and mutual trust between management and employees
- Cross-functional conflicts
- Incompatibility of lean with the company bonus, rewards or incentives systems
- The lack of resources to invest
- Slow response to market
- Lack of information sharing or communication with suppliers and customers
- Lack of cooperation from suppliers
- Lack of influence over suppliers or lack of involvement of suppliers in the actual implementation
- Lack of supplier collaboration or lack of mutually beneficial strategic partnership with suppliers and customers (supply chain members)
- Quality problems with supplied material
- Absence of a sound strategic action/logistical planning system
- Lack of logistic support
- Problems with machines and plant configuration

Jadhav et al. (2014) lists the lean implementation barriers and ranks them according to the total number of resources they searched. They apply a Pareto Chart for lean barriers in the descending order. Since we want to analyse the most encountered barriers, we use the 80-20% rule and take the first eleven barriers for our study.

The lack of resources to invest, lack of top management focus leadership, workers' resistance, cultural difference, lack of top management involvement (commitment and support), lack of perseverance, top management resistance, lack of communication between management and workers, quality problems with supplied material, lack of cooperation from suppliers, lack of influence over suppliers of lack of involvement of suppliers in the actual implementation are the most cited lean implementation barriers.

3. Interpretive Structural Modeling Application

It is necessary to gather expert opinions to apply Interpretive Structural Modeling (ISM) that is used to analyze lean implementation barriers. The preferred analyze method needs to define relationships between each individual barrier as variables.

The defined previously determined lean implementation barriers as variables for ISM application. Experts are asked to express their opinions about variables' relationship determining. Hence, the first and second step of the ISM methodology can be fulfilled.

For instance, experts are asked to determine the relationship between the lack of resources to invest barrier and workers' resistance barrier. Each individual barrier couples are viewed until the whole risks' relationships are defined. The important point for the evaluation is the question to see whether one barrier triggers another or do they have a bidirectional relation.

In order to identify the conceptual relationship between barrier couples, three experts from academy are asked for advice, and related information about experts can be given on demand. As the result of this data gathering process, the obtained relationships of defined barriers are listed.

In order to specify each of these relationships, the frequencies are considered among these multiple expert opinions. Since we have just two experts, the expert opinion aggregation was not complicated.

Interpretive Structural Modeling (ISM) is utilized to clarify and to define the unspecified systems (Sage, 1977). The ISM methodology is used for summarizing the relationships between variables while defining a problem or a subject (Warfield**,** 1974). After this relationship definition process, the hierarchical structure is modelled for the variables.

This technic is usually used so that the practitioners can analyze the unfavorable factors. It can make clear these factors and can indicate the value power based relationships (Mandal and Deskmukh, 1994). The methodology uses variable graphs, directs the relationships, and generates hierarchical models (Singh et al., 2003).

It's a useful tool but there are some shortcomings (Kannan and Haq, 2007). For example, since the expert opinions depend on the experts' individual knowledge, the relationships can be shaped in a nonobjective way. Moreover, as another deficiency, there is no weighted importance level between these variables (Kannan and Haq, 2007).

The ISM methodology includes 8 steps (Kannan and Haq, 2007).

1. Listing the variables of examined systems.
2. Defining the conceptual relationships for these listed variables.
3. Structural Self-Interaction Matrix (SSIM) generation for each couple of variables.
4. Generating reachability matrices by using SSIM, and checking this reachability matrix for transitivity.
5. Transitivity is the main assumption for conceptual relationships of ISM methodology. For instance, if there is a relationship between variable A and B, while there is a relationship between variable B and C, there must be relationship between variable and C.
6. Partitioning the reachability matrix that is created at step 4.
7. Drawing the directed graph by considering the reachability matrix, and removing the links between variables.
8. Transforming the graph to interpretive structural model by replacing the variables with statements.
9. Revising the interpretive structural model for consistency.

The first two steps of the ISM methodology is performed in data gathering section before. In the third step, the Structural Self-Interaction Matrix should be generated. The symbols for relationship definition:

- V: Risk type i affects j.
- A: Risk type j affects i.
- X: Risk type i and j affect each other.
- O: No relationship between i and j risk types.

According to these symbols, the Structural Self-Interaction Matrix is generated and shown in Table 1.

Table 1: Structural Self-Interaction Matrix

	11	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**
1	O	O	A	O	O	O	O	O	O	O
2	A	A	A	A	A	X	X	A	X	_
3	O	O	O	X	X	A	X	A	_	_
4	O	O	O	V	V	O	V	_	_	_
5	A	A	A	X	X	V	_	_	_	_
6	O	O	O	V	V	_	_	_	_	_
7	A	A	A	X	_	_	_	_	_	_
8	O	O	O	_	_	_	_	_	_	_
9	A	A	_	_	_	_	_	_	_	_
10	X	_	_	_	_	_	_	_	_	_
11	_	_	_	_	_	_	_	_	_	_

At the fourth step of the ISM methodology, reachability matrix is created by SSIM, and this matrix should be controlled for transitivity. The generated reachability matrix needs 1 and 0 relationships by replacing V, A, X and O symbols.

- V: (i,j) entrance become 1, while (j,i) entrance become 0.
- A: (j,i) entrance become 0, while (i,j) entrance become 1.
- X: (j,i) entrance become 1, while (i,j) entrance become 1.
- O: (j,i) entrance become 0, while (i,j) entrance become 0.

According to these entrance change, reachability matrix can be created. The reachability matrix is shown in Table 2.

Table 2: Reachability Matrix

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	Driving Power
1	1	0	0	0	0	0	0	0	0	0	0	1
2	0	1	1	0	1	1	0	0	0	0	0	4
3	0	1	1	0	1	0	1	1	0	0	0	5
4	0	1	1	1	1	0	1	1	0	0	0	6
5	0	1	1	0	1	1	1	1	0	0	0	6
6	0	1	1	0	0	1	1	1	0	0	0	5
7	0	1	1	0	1	0	1	1	0	0	0	5
8	0	1	1	0	1	0	1	1	0	0	0	5
9	1	1	0	0	1	0	1	0	1	0	0	5
10	0	1	0	0	1	0	1	0	1	1	1	6
11	0	1	0	0	1	0	1	0	1	1	1	6
Dependence Power	2	10	7	1	9	3	9	6	3	2	2	54

At the fifth step, the reachability matrix is partitioned into different levels. The initial directed graph deriving from the reachability matrix is shown in Figure 1.

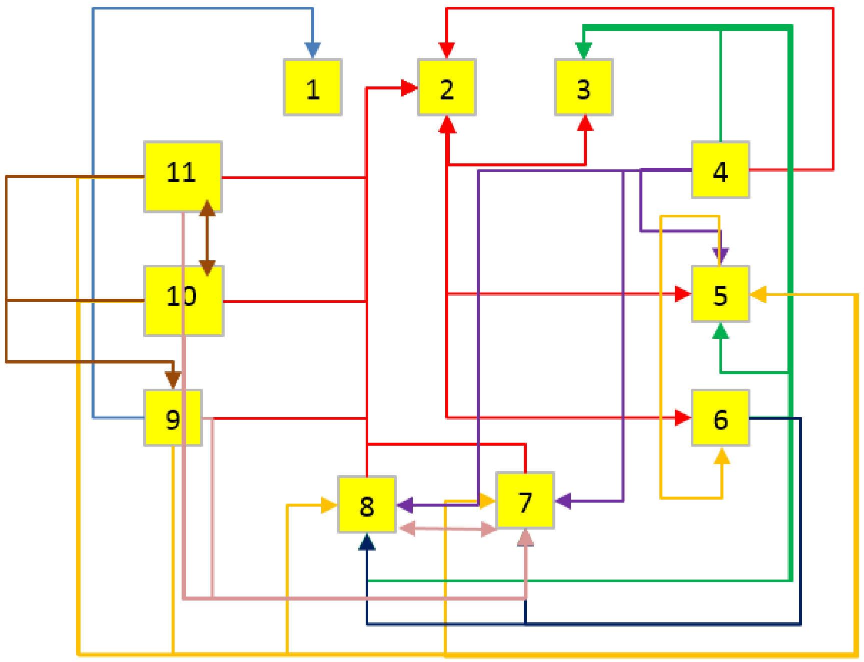

Figure 1: Initial Directed Graph

The final directed graph can be obtained by applying transitivity rules on the initial graph of service supply chain risks. The final graph is useful to determine relationships visually.
According to the initial directed graph, there is enter for 1,2,3,5,6,7,8,9,10,11 nodes. It is not possible to transit from node 1, while there is no entrance to node 4. As it is seen from the graph, node 2, 5 and 7 are highly dependent the others.

By considering the transitivity rules for node 1, there is no chance to reach to enter node 1 except from node 9. We can reach node 2 from all nodes except the node 1. Moreover, we can reach node 3 from node 9, 10, 11 with transitivity rule by passing across the node 5 or node 7. The node 4 cannot be reached, while node 5 is reached by node 6 by transitivity rule. Node 6 is bidirectional with node 2,3,5,7,8. By transitivity rule, node 7 is bidirectional with node 2 and 6. And similarly node 8 is bidirectional with node 2 and 6 by transitivity rule.

After transitivity rule application, the created final directed graph is shown in Figure 2.

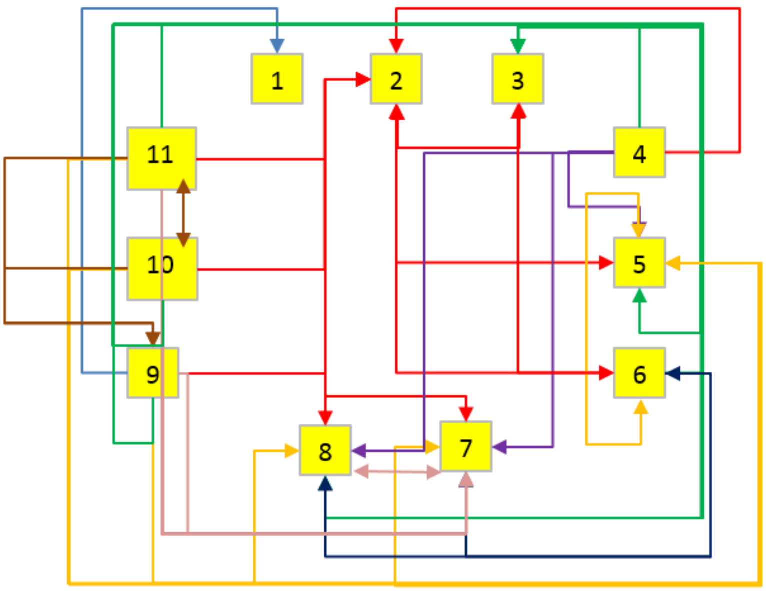

Figure 2: Final Directed Graph

The partitioning process is handled by this final directed graph and it is shown in Table 3. Reachability set includes both the variable and the other variables having interaction with the initial one. Processor set includes the related variable and the other variables that are directed to it.

Table 3: Partitioning for the Reachability Matrix

	Reachability Set	Processor Set	Intersection	Level
1	1,9	1,9	1,9	I
2	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	I
3	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	I
4	2,3,4,5,6,7,8	4	4	
5	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	I
6	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	I
7	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	I
8	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11	I
9	1,2,3,5,6,7,8,9,10,11	9,10,11	9,10,11	
10	1,2,3,5,6,7,8,9,10,11	10,11	10,11	
11	1,2,3,5,6,7,8,9,10,11	10,11	10,11	

After this partitioning process, the intersection set is determined. The intersection set is identified by taking the intersection between the reachability and processor sets, and if the reachability set and intersection set are the same, we can place them into the first level with letter I. The first level indicates the hierarchical relations' top position.

As it is seen from the Table 3, node 2,3,5,6,7,8 have the same intersection level, while node 1 is different from them.

According to the Table 3, the process is repeated for the remaining 4 nodes. After this repeating process, the node 4 and node 9 is placed to the second levels while node 10 and 11 are placed to the third level. The repeating process is shown in Table 4.

Table 4: The Repeating Process for Partitioning

	Reachability Set	Processor Set	Intersection	Level
4	4	4	4	II
9	9,10,11	9,10,11	9,10,11	II
10	9,10,11	10,11	10,11	III
11	9,10,11	10,11	10,11	III

Sequentially, the final interpretive structural model is obtained and it is stated with a visual model which is shown in Figure 3.

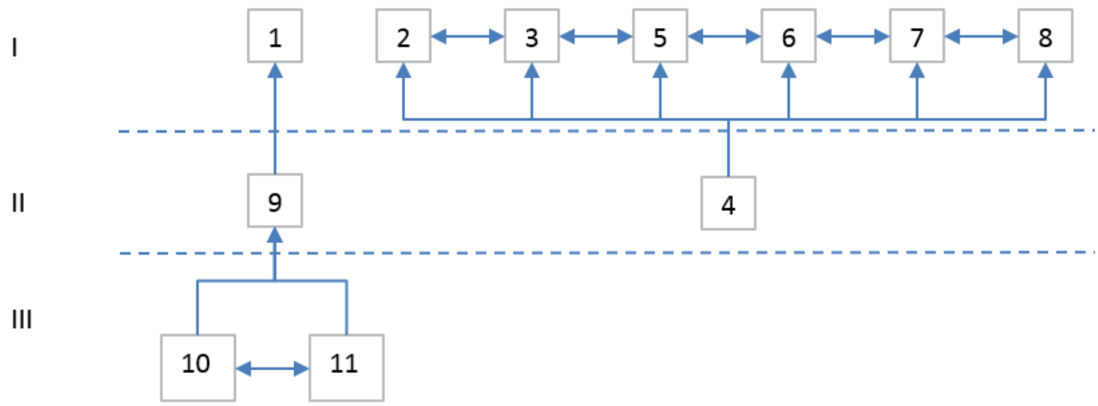

Figure 3: Final Interpretive Structural Model

According to the final interpretive structural model (ISM); lack of top management focus leadership (2), workers' resistance (3), lack of top management involvement (commitment and support) (5), lack of perseverance (6), top management resistance (7), lack of communication between management and workers (8) are all triggered by cultural difference (4). That's why we can infer from the final ISM that interior barriers against the lean implementations are all come from the being unfamiliar with the lean philosophy. Additionally, the other part of the ISM shows that Lack of cooperation from suppliers (10), and lack of influence over suppliers of lack of involvement of suppliers in the actual implementation (11) bring about quality problems with supplied material (9). This quality problems lead to some financial issued which is the reason for the lack of resources to invest (1). We can also interpret that the lean barriers can divided into two sections. First one is about the supplier interaction problem caused internal investment issues, while the second one is about the lean philosophy resistance which is caused be a cultural difference. Finally, we can conclude that there are 2 parallel reasons for lean implementation barriers and we can easily highlight the main barriers triggering the others.

4. MICMAC Analysis

Text MICMAC (Matrice d'Impacts Croise´s Multiplication Appliquee a un Classement/ Cross Impact Matrix Multiplication Applied to Classification) analysis in conducted by evaluating the dependence and the driver power of the barriers. In this analysis, after relation definition and reachability matrix determination processes, the dependence situation of the variables are observed. The variables can be independent, linking, dependent and autonomous (Diabat et al., 2012). When a variable obtains any of these titles, the related variable is placed on a proper cell of the MICMAC analysis matrix.
In the reachability matrix locating at Table 2, barrier 2, 5, 6 3, 8 are highly dependent the others, while barrier 4, 10, and 11 are not. Also we can infer from the driving power column that the barriers are highly triggering each other, except barrier 1. The MICMAC analysis table is shown in Table 5.

Table 5: MICMAC Analysis

	6	B4	B10,B11							B5	
	5			B6,B9			B8	B3		B7	
Driving	4										B2
Power	3										
	2										
	1		B1								
		1	2	3	4	5	6	7	8	9	10
						Dependence Power					

According to the MICMAC analysis, cultural difference is the highest-level independent barrier for lean implementation, while the lack of cooperation from suppliers, and lack of influence over suppliers of lack of involvement of suppliers in the actual implementation are high level independent.
According to the Diabat et al. (2012) definition,

- B4, B10, B11, B6, and B9 are independent variables
- B8, B3, B5, B7,and B2 are linking variables
- B1 is autonomous variable.

This labels show the level of relation dependency of the lean implementation barriers.

5. Conclusion

Lean principles are being highly demanded for many organizations for the sake of their waste elimination and performance improvement benefits. The lean philosophy requires a well dedicated management in implementation phase and it brings about some difficulties to transform traditional systems to lean systems. Therefore, the lean implementation barriers are confronted during the system transformation.

We adopted Jadhav et al. (2014) study's determine lean implementation barriers which are found by a systematic literature review. The most studied barriers are listed as as the lack of resources to invest, lack of top management focus leadership, workers' resistance, cultural difference, lack of top management involvement (commitment and support), lack of perseverance, top management resistance, lack of communication between management and workers, quality problems with supplied material, lack of cooperation from suppliers, lack of influence over suppliers of lack of involvement of suppliers in the actual implementation.

In the following step of our research, we ask for their expertise to academicians so that they can examine the each individual barriers' relations. They identified whether there is a relation between the barrier couples, if there are, they determined the direction of the relation. They described which barrier trigger the one another, or there is a both directed triggering relation. The expert ideas are all gathered to apply the Interpretive Structural Modeling (ISM) and MICMAC Analysis which are suitable tools to point the root cause of the barriers.

ISM highlights the hierarchical lean implementation barrier model, and shows us that we can classify the barriers as supplier interaction problem caused internal investment issues and lean philosophy resistance which is caused be a cultural difference. According to ISM application, there are two parallel reasons for lean implementation barriers and we can easily highlight the main barriers triggering the others.

MICMAC analysis demonstrates that cultural difference is the highest-level independent barrier for lean implementation, while the lack of cooperation from suppliers, and lack of influence over suppliers of lack of involvement of suppliers in the actual implementation are high level independent.

These two analysis gives us similar results which are based on dependency situation of the lean implementation barriers. There is a little difference between the results and the reason behind this difference is that the ISM application requires a transitivity rule which links the barriers in an indirect way.

Our study provides with managerial implication that organizations should focus on their suppliers and their cultural difference of lean philosophy. Both internal and external education and training programs should be provided in order to handle the lean implementation barriers.

The limited number of the lean implementation studies in and the possibility of the biased expert opinions for analysis structure are the main constraints of this paper. The long term researches with both academicians and sector experts can be conducted in order to handle with this problems. Furthermore, any other data gathering and analysis technics can be applied in the field of lean implementation barriers.

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A Simulation Model to Evaluate Treatment Services Reconfigurations for Patients with Parkinson's Disease

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Abstract

Parkinson's disease (PD) is the second most common chronic neurodegenerative condition in older people especially beyond the age of sixty. PD has a multitude of symptoms and its treatment and patients' management is complex and resource intensive due to the multidisciplinary team required to treat it and maintain quality of life for patients, and provide appropriate end of life care. Current evidence suggests that PD treatment spending is increasing and there is a need to find innovative treatment procedures such as the use of community services (CS), which are cheaper than hospitals and easier to access by patients A Discrete Event Simulation model was built to represent the PD care pathways and treatment procedures until end of life. The model represented PD disease stages, modes of treatment in hospitals and CS, and the mix of resources required to provide treatment, and was calibrated using data from the United Kingdom (UK), and in. The model was used to test a number of scenarios whereby the number of patients shifted to CSs is increased by 10%, 20%, 30%, and 40%. The results suggest that these policies will have a positive impact on the number of patients' visits to hospitals, overall cost of treatment, and the number of PD doctors and nurses in hospitals. CS should be formally integrated in treatment guidelines and more staff are trained to provide care in CS. Integration between clinical and social services, which are in charge of CS, should be improved to provide better quality of care.

Keywords

Parkinson's disease, community services, Discrete Event Simulation, United Kingdom.

1. Introduction

Neurodegenerative conditions and motor neurone affecting cognitive and physical ability have life changing impact on individuals, families and carers. Medical interventions are of limited benefit for these progressive illnesses if social care and support for managing daily activities is lacking. Fundamental to the management of such conditions is the coordination of care across different health and social care sectors. From a health systems perspective, models of integrated and efficient service delivery and care are required particularly in the context of aging populations; a challenge particularly in high income countries. Impact extends across the healthcare economy (primary, community, secondary and tertiary care) as well as to other public services including transport, employment and housing needs (National Audit Office, 2011). For long-term progressive conditions, key questions arising are *which treatment pathway?* and *where?* To achieve the best outcome for patients and healthcare providers. To answer these questions we focus on one particular condition, Parkinson's disease (PD) in a country where the population is ageing rapidly, the United Kingdom (UK).

PD is the second most common chronic neurodegenerative condition in older people especially beyond the age of sixty (De Rijk, et al., 1997). PD symptoms are numerous and include motor symptoms such as stiffness, tremor and lack of mobility, and non-motor symptoms such as depression, psychotic symptoms, dementia, sleep disturbance, fall, and autonomic disturbances. As a result, the treatment and management of PD patients is complex and resource intensive due to the time between onset of symptoms and diagnosis, the multidisciplinary team required to treat it and maintain quality of life for patients, and provide appropriate end of life care.

There are currently about 127,000 people in the UK living with PD and this is expected to increase to 165,000 by 2020 (Parkinson's UK 2011, 2012). Current evidence suggests that the National Health Service (NHS), the public body in charge of providing healthcare in the UK, is struggling to cope with the demand. A National Audit Office report found that although access of patients with neurological conditions including PD to health services improved since 2007, spending increased by 38 percent in real terms and the quality of care worsened during the same period (National Audit Office, 2011). Just over half (66%) of General Practitioners (GPs) referrals meet the National Institute for Clinical Excellence (NICE) guidelines of a specialist appointment within 6 weeks and 14% of patients are readmitted after 28 days of discharge. Recent work has shown that less than quarter of PD patients (22%) have a personal care plan (Fitzpatrick et al., 2010).

This situation is alarming especially that the NHS is faced with additional pressures stemming from ever increasing resource and capacity constraints (e.g. reduction in budgets, fewer doctors and nurses, reduced number of hospital beds). Taking in consideration the fact that the NHS has a target of making a net savings of £20 Billion over the coming 4-5 years (Harn, 2010), then the need for efficiency improvements becomes clear.

In this new reality of “doing more with less”, it is necessary to identify areas where efficiency gains can be made. This is challenging in the case of PD as each individual patient’s requirement depends on the severity and stage of their condition. A better understanding of the impact of different care pathways and configuration of service options is needed. On the one hand efficient, whilst being flexible enough to allow for individualised management plans to be realised. Some patients may be seen by neurologist on a monthly basis, while others quarterly; Parkinson’s specialist nurses may see some patients once a month, whereas others twice a year; in addition, PD patients are generally referred to a combination of community services (CS) depending on the stage of their disease, such as physiotherapy, psychiatry, speech and language therapy, occupational therapy, dietician and palliative care. Physiotherapy can improve balance and flexibility; improve functional independence, including mobility and activities of daily living. Occupational therapy improves personal self-care activities, such as eating, drinking, washing and dressing; maintain work and family roles, employment, home care and leisure activities. Speech and language therapy optimises speech intelligibility, ensuring an effective means of communication throughout the course of the disease. Effective deployment of community services is considered key to improving quality of life, increasing patient understanding of their own disease journey while empowering them to better self-manage their own condition. This is why community services have been well received and praised by patients who feel that they are effective (NICE 2006).

From the health delivery perspective, it is thought that increased use of community services could potentially reduce unnecessary hospital admissions, reduce the need for consultations with specialists and facilitate the earlier discharge of patients from hospital with support in the community (NICE, 2006). In many cases, commissioners would prefer more use of primary care in the community as opposed to secondary care provided in hospitals, simply because primary care is generally much cheaper than secondary care. The average cost to treat a PD patient admitted to inpatient care as an emergency admission is £2,133 (based on an average length of stay of 6.3 days) and the average cost of a neurologist visit is around £145. In contrast, the costs associated with community services are in the region of £38 to £98 (e.g. physiotherapy £38, occupational therapy £56 and speech and language therapy £98) (Department of Health, 2012).

Given the strong case for making efficiency gains in the delivery of PD care, it is very surprising that there is little research on how the reconfiguration of care pathway and the use of innovative and less expensive treatment settings such as community services could lead to efficiency gains for the care providers. The literature covering this issue includes the 2011 report by the National Audit Office mentioned above and a recently published research providing some evidence that the use of community services reduces PD doctors and nurses’ activity levels (Demir et al, 2015). There is clearly a gap in research, which warrants further investigation.

The current study comes into the context of this research gap and aims to explore the impact of possible changes to the PD care pathways and how these could impact the performance of the PD care delivery. This is achieved by developing a simulation based decision support toolkit, which represents the different stages PD patients go through as they are diagnosed, treated, and managed, the different modes of treatment in hospitals and community services, and the mix of resources required to treat and manage patients. The toolkit is user friendly and allows evaluation of alternative care pathways configurations and is, therefore, valuable for key decision makers in the process of commissioning and re-designing services.

In the next section, we review the literature on the management of PD patients and the modelling methodology selected in this study. In section 3 we describe the model building process including PD patients’ pathways and the categories of data included in the model. Section 4 focuses on the policy scenarios analysed in the model and their associated results. The paper concludes with a discussion and conclusion section covering the implications of the results for practice and the relevance of the methodology for health policy.

2. Literature Review

2.1 Management of patients with Parkinson's disease

Parkinson's disease (PD) is a progressive neurodegenerative condition, which affects people aged 60 or more (NICE, 2006; Olanow et al., 2001). The most common early symptoms of the disease are problems with movement and this includes tremor, stiffness, slowness, and paucity of movement (Nutt and Wooten, 2005). The disease continues to progress until late phases, which are generally characterised by increased motor complications, disability, and mortality (NICE, 2006; Nutt and Wooten 2005).

The management and treatment of PD is a complex process as it affects older adults who may also be suffering from other conditions, the difficulty to diagnosis the disease, its progressive nature due to the inexistence of a known cure for it, the involvement of several services in its treatment, its severe psychological effects, and given that its impact goes beyond the patient to families, employers, and public services (National Audit Service, 2011; NICE, 2006).

The disease includes four phases (Parkinson's UK 2012), which impact directly on the treatment provided to patients. The Diagnosis phase reflects the initial stage when a patient is suffering from PD like symptoms and signs, but there is no formal confirmation that the patient has PD. Once the diagnosis tests are conducted and PD confirmed, the patient moves to the Maintenance phase. Depending on the patient status, either no treatment is provided at this phase or a treatment involving small doses of one or two drugs is given. As there is no cure for PD, the aim of the treatment is to slow the progression of the disease so that the patient quality of life is not affected. As the symptoms worsen and more functions of the body are affected, the patient enters the Complex phase in which the number of drugs and their doses are increased and, in some cases, neurosurgery is performed. The final phase, known as Palliative, is characterised by high risks of physical and mental disabilities and significant threats to life.

The treatment pathways for PD are complex and involve inpatient, outpatient, and community care and require a range of clinical specialists (Demir el al., 2015). The inpatient care involves drug treatment and surgery in hospitals. Outpatient care provides drug treatment and specialist therapies such as Physiotherapy, Psychiatry, Occupational Therapy, and Speech and Language Therapy. This care takes place in GP clinics and hospitals. Community care is similar to outpatient care, but it is provided in local community care units with the support of community pharmacies and social services.

The evaluation of the treatment and management of PD patients with PD has been significantly dominated and centred around the patients and their quality of life and far less on the performance of the system delivering care to patients. Several studies investigated the relationship between PD and quality of life. For example, a study by Karslen et al., (1998) in the UK found that patients with PD perform much worse that patients with Diabetes or with elderly people not suffering from a chronic disease in terms of physical mobility, emotional reaction, social isolation, and energy. Depression, disability, and cognitive impairment were found to be significantly related to lower quality of life in PD patients especially as the disease progresses over time (Schrag, 2006; Schrag et al., 2000). The significant impact of PD driven depression and low degree of independence on quality of life was highlighted by Behari, Snvastava, and Pandey (2005) in a study covering patients in India. A more recent study in Slovakia investigated the effect of a wide range of medical, emotional, and social factors on quality of life for PD patients. The results show that emotions, cognitive functions, and mobility had a significant impact on quality of life and the ability of patients to carry out their daily activities (Slezakova et al., 2013).

However, there has been virtually no research looking at the performance of the system delivering care for PD patients. A surprisingly low number of studies attempted to investigate this aspect. A report by the National Audit Office in the UK shed some light on this issue and found that access of patients with neurological conditions including PD to health services has improved since 2007. However, this was offset by an increased spending of 38 percent in real terms between 2006-07 and 2009-10 and worsening of quality of care (National Audit Office, 2011). On the academic side, a recent study by Demir et al., (2015) conducted in the UK found that shifting some aspects of PD care from hospitals to community services has a positive impact in terms of reducing the level of activity and the number of specialised nurses delivering care to PD patients.

2.2 Discrete Event Simulation (DES) in Health Management

There has been an increasing number of Simulation Modelling including DES in Health Management since the 1990s driven by the increased complexity of health care systems, the considerable advancements in DES software capabilities and ease of use, and the shift to more evidence based decision making in the health sector (Ansah et al 2013, Ghaffarzadegan et al., 2013; Gunal and Pi,dd 2010; Brailsford et al., 2009) This is reflected in the literature reviews conducted on DES in Health Management, which show an upward trend in terms of the number of DES applications and the areas covered by these applications (Gunal and Pidd, 2010; Jun et al., 1999).

Given their critical importance in healthcare delivery, an important fraction of DES applications in Health Management was devoted to the modelling of patients' flows and pathways. Swisher et al., (2001) developed a model to study the performance of physicians in an American clinic and covered elements such as the clinic layout, treatment stages, categories of resources required for treatment of patients, and the types of medical conditions treated in the clinic. The model was used to test different scenarios regarding staffing levels and facility size and their effect on the financial performance of the clinic, and patients and staff satisfaction. In another model developed by Brailsford and Schmidt (2003), behavioural aspects of patients were integrated into a model representing screening of diabetic retinopathy in the UK. The disease is a Diabetes complication and affects the human sight leading to blindness, hence the importance of the screening process. The model represented the physical and behavioural factors affecting screening attendance compliance and were combined to generate scenarios, which were evaluated to determine their impact on the number of total years of sight saved over a 25 years period. Policies to prevent mother to child transmission of HIV/AIDS in Tanzania were studied by Rauner, Brailsford, and Flessa (2005). The model combined the evolution of the female population including birth, aging, pregnancy, and giving birth with the natural history of HIV/AIDS, that is HIV infection, progression to AIDS, and its treatment. Policies including providing babies with Anti-retroviral treatment at birth, bottle feeding strategies, and a combination of both were analysed to determine the number of HIV/AIDS deaths, which could be prevented. Pligrim et al. (2009) investigated the cost effectiveness of care options for patients with bowel cancer in the UK through a model representing key events such as patient presentation, referral and diagnosis, treatment, follow up, possibility of recurrence, treatment, and end of life. Thirteen care options were evaluated with respect to criteria including incremental life years gained, quality adjusted life years, and the cost per life year gained.

More recently, DES has been combined with optimisation techniques. Petering et al., (2015) developed a model linking reimbursement policies with sustainability performance criteria (cost, environment, and social wellbeing). The model represented patients' pathways from admission to discharge, categories of resources, and the types of care provided in Cardio-vascular disease unit in the United States Several scenarios were tested to determine near optimal cost reimbursement policies, staffing levels, and the number of beds that maximised profits to investors while satisfying sustainability performance criteria, Another simulation-optimisation model by Van Huele and Vanhoucke (2015) on scheduling of operating theatres in a Belgian hospital enabled managers to determine doctors' allocation policies. The objective was to maximise the number of patients treated and minimise the amount of overtime work taking into account social factors such as doctors' preferences in terms of the days they would like to work on and the number of operations they would like to perform on a given week.

3. Simulation Model Development

The model was commissioned by health care providers and a pharmaceutical company, which develops drugs used in the treatment of PD and was developed in collaboration with health care professionals and potential end-users. The process started with a meeting with the National Committee of the Parkinson's Disease Nurse Specialist Association (PDNSA) in late 2012. Six PD specialist nurses were involved and provided detailed information regarding patients' pathways, resources required in the diagnosis and treatment of PD, and the rules and policies associated with the management of patients. Semi structured interviews were conducted with the nurses and led to an initial mapping of the PD patients' pathway structure. This map was further developed and refined through structured interviews with members of the PDSNA national committee, who checked that the initial map reflected the patients' pathways and suggested corrections where gaps were identified.

3.1 The PD patients care pathway structure

The interviews with PD nurses indicated that the first point of contact of a patient with the PD care system is a visit to a PD outpatient clinic following referral from a GP, Accident and Emergency (A&E) units, outpatients, or other hospital departments. Diagnostic tests are carried out on the patient, and, if PD is confirmed, patients are categorised into one of the disease phases (Diagnosis, Maintenance, Complex or Palliative) and treatment commences. The treatment is supervised by a PD specialist and takes the form of a referral to surgery, treatment via drugs, use of community services, or a combination of these modes (See Figure 1). The PD specialist is supported by PD specialist nurses, who play a critical role in the management of PD patients and determination of their treatment needs.

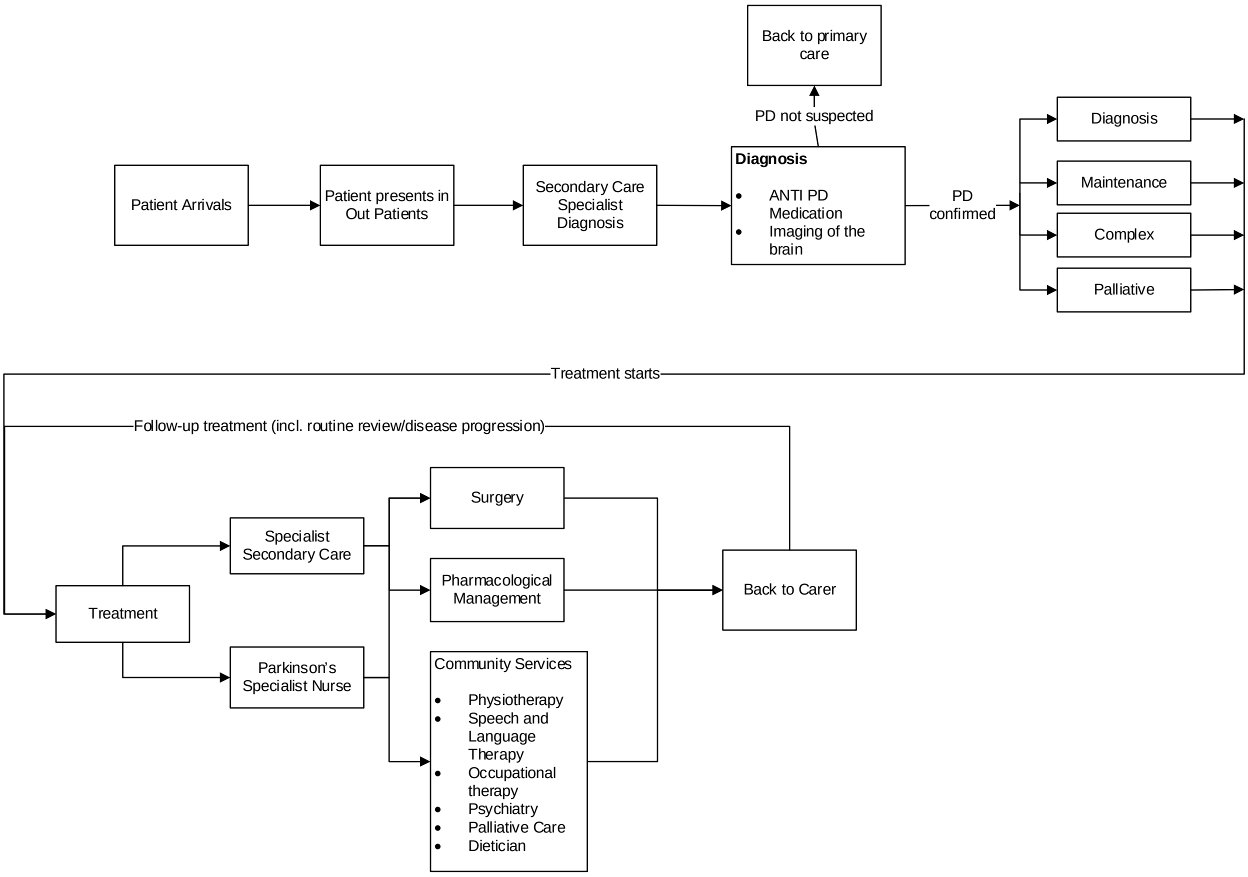

Figure 1: Structure of the Parkinson's disease (PD) patients' pathway

As there is no known cure for PD, the treatment is continuous. Patients in the Diagnosis, Maintenance, Complex and Palliative phases meet with the PD specialist and PD nurse 2, 4, 5 and 6 times a year respectively. In these meetings, disease progression is evaluated and decisions about changes to the mix of drugs to be given to the patient are made. Requirements regarding the use of primary care or community services (eg Physiotherapy, Speech and Language Therapy) are also determined in these meetings depending on the medical status of the patient.

The simulation model capturing these pathways was built using the software SIMUL8 (www.simul8.com) and represented the entry point to the PD care system, progression through disease phases, treatment processes and resources, and the use of community services. As the model is aimed for decision makers, a friendly and easy to use interface was added to allow users to test policies regarding changes to demand levels, patient pathways, allocation of resources, and disease progression (See Figure 2). These policies are represented as scenarios on the model, and, once a scenario run is completed, the model generates a results summary on the key performance indicators of interest to decision makers (these are shown on the model interface). A complete set of results can be exported to an Excel spreadsheet to enable more detailed analysis.

3.2 Model parameters and validation

Several sources of information were used to estimate the values of the parameters entered in the model. The NHS English Hospital Episodes Statistics (HES) data set (the biggest and most comprehensive official health statistics database in the UK) and interviews with PD specialists were the sources for parameters regarding origin of referrals, PD progression and treatment, and provision of community services.

Given that PD treatment in the UK is decentralised and entities (called NHS Trusts) are responsible for providing care at a regional level, the parameters related to the number of patients and treatment modes were estimated from one big NHS Trust, which provides full treatment modes including community services. In this Trust, the breakdown of new PD patients by source of referral is 75%, 15%, 5%, and 5% for GP, A&E, outpatients, and other hospital department respectively. The distribution of patients by disease stage category is mostly constant at 10% Diagnosis, 60% Maintenance, 25% Complex and 5% Palliative. Visits to PD doctors occur once a year in the Diagnosis phase, 2 to 3 times a year in the Maintenance phase, and 3 to 4 times a year in the Complex and Palliative phases. Patients are seen 2 to 4 times a year by a PD nurse except in the Palliative stage where a customised care plan is designed and patients are seen by a PD nurse once a month.

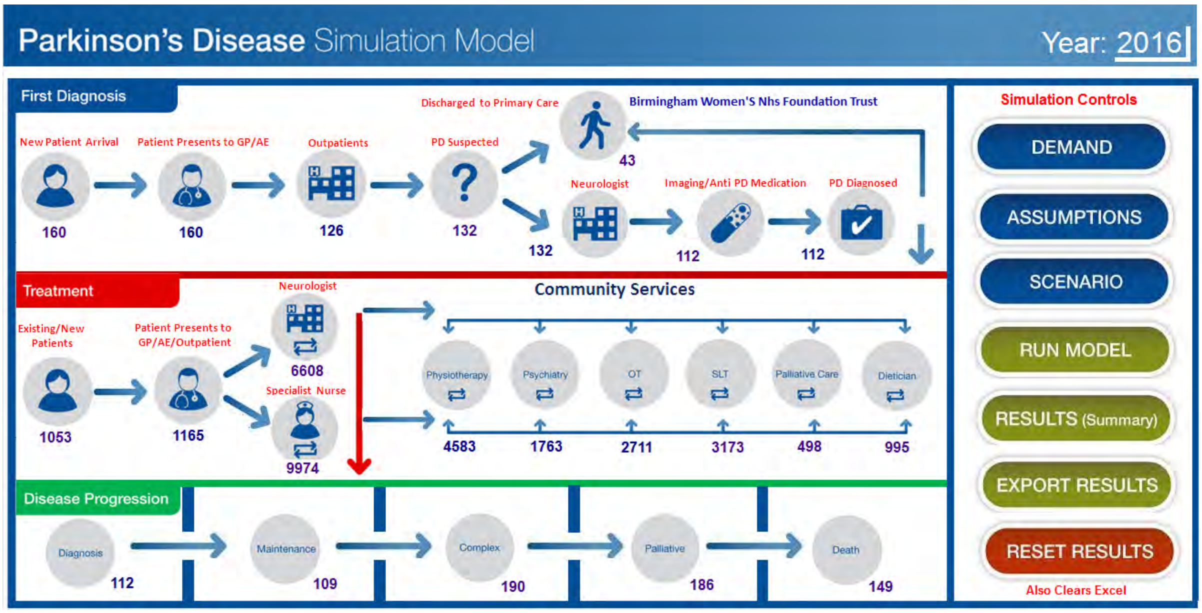

Figure 2: The Parkinson's disease (PD) simulation model user interface.

Information regarding the use of community services is scarce and mostly unrecorded, so the research team relied on the extensive experience of PD nurses to estimate these parameters. Following interviews, we determined the percentage of patients referred to community services including those using a single service (eg physiotherapy) or a combination of services (eg speech and language therapy and occupational therapy). The number of visits per year and the resources required in these visits were also determined from the interviews.

The unit costs associated with the different modes of treatment (hospital, outpatient, community services) were determined using the Healthcare Resource Group (HRG) code, which provide standardised and reference costs for the treatment of different diseases and clinical conditions in the UK (these are publicly available) Extra costs were included to reflect instances of unexpectedly long stay in hospitals or additional treatments and tests. The number of staff available and their salaries were determined from interviews. (A full set of data used in the model is available from the authors on request).

The model was put to validation tests to ensure that it can be confidently used to simulate alternative scenarios and design policies out of their results. The tests covered two aspects: (i) the model's ability to replicate historical observations and (ii) the correct representation of the PD care system (face validity). Data representing the current situation was entered into the model and then run for a period of 3 years. The generated results were very close to those observed in the real world. For example, the average number of PD nurse visits obtained from the model was 11,106 compared to 11,730 in the real world and the average number of PD doctor visits was 9,558 from the model versus 9,350 in the real world.

Face validity was performed by showing the model to each nurse individually and then to all nurses in a group workshop. The model structure was confirmed to be highly representative of the real world PD care system by all nurses. The engagement of the nurses and their continuous involvement and feedback was instrumental in achieving face validity for the model.

4. Simulation Scenarios and results

Given that the aim of the model is to assess how shifting more patients to community would impact the operational and financial performance of the PD care system, three scenarios were selected by decision makers for evaluation: (i) "Scenario 1: Low increase in community services", (ii) "Scenario 2: Medium increase in community services", and (iii) ""Scenario 3: High increase in community services". The relevant model were changed to reflect these scenarios.

To achieve robustness of the results, each scenario was run 100 times (using different random numbers each time) for a period of three years with a "warm up" period of 1 year. Results were collected on the performance indicators, which grouped in 3 categories: "Number of Visits", "Service Cost", and "Resource Utilisation". The results for the 4 scenarios are summarised in Table 1.

Table 1: Simulation results for community services usage scenarios

Performance Indicator	**Baseline**	**Scenario 1: Low use of CS**	**Scenario 2: Medium Use of CS**	**Scenario 3: High Use of CS**
PD doctors' visits	8225	7494	7158	6537
PD nurses visits	10357	9854	9553	8831
Physiotherapy visits	3554	3700	4036	4708
SLT visits	3357	3494	3811	4447
Psychiatry visits	1776	1850	2019	2355
Occupational therapy visits	2335	2420	2640	3079
Palliative care visits	454	477	519	606
Dietician visits	434	456	496	579
PD doctors total FTEs	1.07	0.97	0.93	0.85
PD nurses total FTEs	3.4	3.2	3.1	2.9
PD doctors cost	1,809,500	1,648,680	1,574,760	1,438,140
PD nurses cost	1,553,550	1,478,100	1,432,950	1,324,650
Total Hospital Costs	**3,363,050**	**3,126,780**	**3,007,710**	**2,762,790**
Physiotherapy cost	135,052	140,600	153,368	178,904
SLT cost	322,272	335,424	365,856	426,912
Psychiatry cost	88,800	92,500	100,950	117,750
Occupational therapy cost	135,430	140,360	153,120	178,582
Palliative care cost	22,700	23,850	25,950	30,300
Dietician cost	21,700	22,700	24,800	28,950
Total community services cost	**725,954**	**755,434**	**824,044**	**961,398**
Total cost	**4,089,004**	**3,882,214**	**3,831,754**	**3,724,188**

SLT: Speech and Language Therapy

An analysis of these results suggests the following

- <u>*Number of Visits to Hospitals:*</u> The results suggest that shifting more patients to community services will ease the burden on hospital staff in terms of number of visits. The reduction for PD doctors is quite significant as visits are expected to decrease from 8225 under the baseline scenario to 6537 under scenario 3 representing a decrease of 21%. Similarly, PD nurses, a critical resource in the hospital based PD treatment system, will see their level of utilisation drop by 15% from 10367 to 8831 visits under the baseline and scenario 3 respectively.
- <u>*Level of Resources:*</u> It can be observed from the results that the number of Full Time Equivalent (FTEs) of staff required for hospital treatment will be 3.75 FTEs under scenario 3 compared to 4.47 FTEs under baseline scenario. This is valid for both PD doctors and PD nurses with the latter going down by 15% from 3.4 FTEs (baseline scenario) to 2.9 FTEs (scenario 3). This outcome suggest that hospital staff workload is expected to ease should the scenarios be implemented in practice.
- <u>*Treatment Costs:*</u> An analysis of the result leads to the conclusion that overall treatment costs will go down as scenarios involving higher use of community services are implemented (See Figure 3). This decrease is driven by savings made in the hospital treatment costs, which are reduced by 18% from £3,363,050 to £2,762,790 as we move from baseline to scenario 3. This is despite overall community services costs moving upwards by 32% from £725,954 to £961,398. The overall costs gains are achieved due to the significant difference between treating patients in hospitals and community services. The augmentation in community services costs are well offset by the reduction in hospital treatment costs leading to a decrease in overall treatment costs.

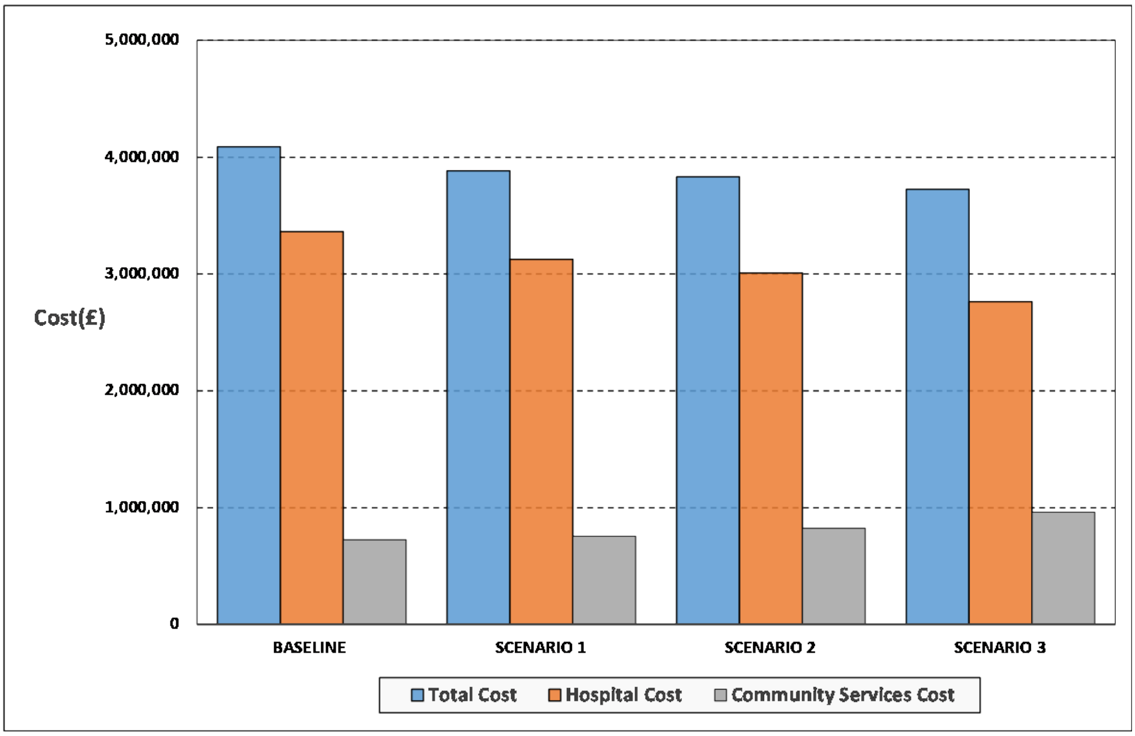

Figure 3: Hospital, community services, and total treatment costs for community services usage scenarios

5. Discussion and Conclusion

The number of patients affected by PD is increasing and this trend is expected to continue and get stronger in the future as populations shift towards higher age (Parkinson's UK 2011). This is occurring at times of budget austerity and inflated treatment costs putting pressures on decision makers to find innovative ways to deliver care in a significantly more efficient way. The research comes against this background and explores the possibility and scale of efficiency gains, which could be achieved should Community Services become an integrated part of PD treatment (NICE, 2006)

The results indicate that adoption of Community Services could lead to positive outcomes in the form of lower treatment costs and reduced pressure on hospital staff. These are welcomed news to policy makers as this means that there is a possibility to absorb higher demand for PD treatment without causing significant disruptions to hospitals and major increases in cost

In addition to the benefits from the care delivery perspective, there is strong evidence that patients find Community Services to be a friendly environment in which staff are committed to the delivery of a personal and high quality care to patients (Parkinson's UK 2012). This "human" aspect has been highlighted by the advocates of a wider use of these services as they point out that the positive psychological impact on patients is as important as the treatment especially if we factor in the facts that PD affects senior people who may already suffer from social exclusion in addition to the non-motor symptoms of PD such as depression and dementia. This gives more momentum to the idea that the integration of health delivery with social services for the elderly people can be a good way forward and can contribute to reverse PD patients' low satisfaction with the quality of care currently provided (Parkinson's UK 2012; National Audit Office, 2011). The current PD treatment policies will, therefore, need to be updated so that the use of Community Services becomes a formal element of the treatment pathways and procedures.

From a policy making perspective, a wider adoption of Community Services comes, of course, with its own set of challenges. In the UK context, there are significant regional variations with regard to these services as they tend to be much more available in towns and urban areas than in villages and rural areas. Sufficient well trained Community Services staff are also in short supply, which constraints the expansion of these services in news areas of the country. Rising awareness among patients of the existence and benefits of Community Services is also an issue for policy makers to deal with.

The model was developed with the active engagement of policy makers and staff involved in the PD care system. This collaborative effort led to a feeling of problem ownership by the stakeholders and was a critical factor in the adoption of the model and its results. This positive outcome was also facilitated by the increasingly friendly and easy to use Simulation software, which is lowering the technical barriers faced by health managers and enabling them to play a more assertive role in building and using simulation models. This can only improve the decision making process as it has been observed that in several instances, health managers had a clear idea about the decisions to be made to improve performance, but lacked the evidence to make a case to decision makers. By providing that evidence, simulation modelling fills this gap and allow policies to be selected and implemented with a clearer vision towards the future.

The successful application of Simulation Modelling in this context and the enthusiasm and engagement of key participants in this research strengthens the argument that this approach can play a critical role in the improvement of policy making and performance of health systems. As the complexity of these systems continues to grow in an environment of constrained resources, the need for evidence based decision making will become stronger. Simulation modelling is well positioned to provide that evidence and allow policy makers to face the upcoming challenges with greater confidence.

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Biography

Reda Lebcir is a Senior Lecturer in Management Science at the University of Hertfordshire. He graduated with a BEng in Industrial Engineering from the Ecole Nationale Polytechnique in Algeria, MSc in Operational Research from London School of Economics and a PhD in Management Science from Imperial College London. His current research interests are in the areas of Management Science, Simulation Modelling, Project Management, and Health Management. He has been involved in several research projects and published in many international conferences and academic journals such as the *Journal of the Operational Research Society*, *Health Policy*, *International Journal of STD and AIDS*, *International Journal of Project Management*, *International Journal of Electronic Healthcare*, and the *International Journal of Production Research*.

Eren Demir is involved in the use of modelling techniques in healthcare management, and the development of tools that can aid healthcare decision-making. He has participated in many research/consultancy projects, including capacity planning; forecasting demand and cost; re-design of services to improve clinical outcomes; data mining to capture hidden patterns and trends; simulation of patient pathways; evaluation of service outcomes, and development of models to measure cost effectiveness. He has published widely in the area of healthcare modelling and decision support systems. Since 2004 he has been lecturing in undergraduate and postgraduate statistics and operational research. Eren is also Director of Modelling and Analytics at Pathway Communications Ltd

Tahar Boukhobza is an Associate Professor in Marketing at university of Algiers and an external doctoral supervisor at Anglia Ruskin University in the UK. Prior to that he was an Associate Professor at the American University in London where he also held the position of the head of department in marketing. He has extensive teaching experience at both undergraduate and postgraduate level in UK universities (University of Salford, The American University in London) in the areas of marketing and management. He also delivered workshops and professional courses to a number of companies in Algeria and has been involved in a number of consultancy projects in the UK and overseas. His research area is mainly in marketing & management and Islamic Banking.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A Timetabling Approach: Optimal Exam Schedule in a University

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Abstract

Exam timetabling has received much attention in the literature over the years. However, each university has specific constraints, rules and objective function. Therefore, studies in the literature cannot be adapted to our exam scheduling problem, which motivates us to conduct this research. The exam timetabling problem involves assigning predetermined exams to available timeslots, classrooms, proctors to classrooms, etc. Rules and regulation play a role in examination of scheduling problems. The focus of this paper is to develop a mathematical model to assign the examinations of each department to the propose timeslots in a given examination period. We address a real problem occurring at the İstanbul Bilgi University Faculty of Engineering and Natural Sciences. We validate our model using the data collected from the university, show that our model is tractable in practice and can be solved in a reasonable amount of time.

Keywords

Exam timetabling, mathematical model, operations research, scheduling

1. Introduction

In many schools, course and examination timetabling fall under the responsibility of management. Previously, these timetables were usually generated by making small changes to the previous timetables with respect to the changes in the curriculum. Nevertheless, in recent years, curricula are changed frequently and rapidly which complicates the usage of previous years' timetables. Therefore, a need of a good software implementation in the educational institutes arises to timetable both courses and examinations in an automated way.

The emphasis of this study is the educational timetabling problem, which is a very challenging problem to solve especially with a high number of the departments, classes, and students. Due to the large scale of educational timetabling problems and preferences of the stakeholders, it is almost impossible to form a general model that solves all of the timetabling problems in the literature. This resulted in the need to develop and employ specific models for specific institutions.

In the literature, there have been several descriptions of the timetabling problem. Wren (1996) defines the timetabling problem as a certain type of scheduling problem which aims to assign certain resources such as students and examinations to a limited number of classrooms and timeslots which can vary by institution. The timetabling problem is a well-known NP-Hard problem (Dammak et al, 2006). Therefore, finding even a feasible solution is extremely hard. Specific requirements of universities, which add more constraints to the problem, make this problem harder to solve.

According to Burke, Eckersley, McCollum, Petrovic and Qu (2004), the timetabling problem consists of four parameters: T, a finite set of times; R, a finite set of resources; M, a finite set of meetings; and C, a finite set of constraints. The objective is to assign time and resources to the meetings intelligently such that the constraints are satisfied. The purpose of this study is to develop a mathematical programming model that solves the examination timetabling problem at the İstanbul Bilgi University Faculty of Engineering and Natural Sciences. This problem will be defined as a Constraint Satisfaction Problem (CSP) where any feasible solution of the model will be acceptable and there will not be an objective function in the model.

The rest of this study is organized as follows. In Section 2, related research in the literature is summarized. In Section 3, the problem in the İstanbul Bilgi University Faculty of Engineering and Natural Sciences is define. In Section 4, a constraint programming model is developed, and the constraints are explained. In Section 5, results are discussed, the model is verified, and the study is ended with conclusions.

2. Literature Review

Educational timetabling problem is one of the most widely studied timetabling problems. Generally, in the literature, the educational timetabling problems are divided into sub-research areas such as examination timetabling and course timetabling. For these problems, not only exact methods but also heuristic approaches are provided by many researchers.

One of the earliest researches for examination timetabling was done by Broder (1964) whose objective was to minimize the number of student conflicts. The author presented a heuristic algorithm of the "largest degree first" method. For the examination timetabling problem, a computerized examination timetabling system called EXAMINE was developed and implemented at the University of Toronto and at Carleton University by Carter et al. (1996). Alvarez-Valdes, Martin and Tamarit (1996) solved the Spanish school timetabling examination problem with the help of a heuristic that they developed. Taking into consideration the classes, teachers, subjects and rooms, they scheduled lessons within the school week. The problem could also be viewed as resource-constrained project scheduling problem (RCPS). Similar to the Spanish school timetabling problem, for the secondary educational system in Greece, Birbas, Daskalaki and Housos (1997) worked on a timetabling problem, and optimally solved it by 0-1 integer programming and demonstrated the effectiveness of the model in satisfying both the hard and soft constraints.

Dimopoulou and Miliotis (2000) constructed a model for exam timetabling problem in a Greek University. Integer programming (IP), Graph coloring, Heuristics, Tabu search (TS) were applied. They intended to find a feasible schedule. Another study about examination timetabling was accomplished in the National University of Singapore by Lim et al. (2000) where they developed a system called UTTS Examination Scheduler in which they defined their problem as both constraint satisfaction problem and an optimization problem. Burke and Petrovic (2002) constructed a model for exam timetabling problem in a Nottingham University. Heuristic and meta-heuristic methods were applied. Duong and Lam (2004) constructed a model for exam timetabling problem in a Ho Chi Minh City University. Sequential Construction Heuristics, Constraint Programming, and Local Search were applied.

Dammak et al. (2006) have observed how a set of non-conflicting examinations, that have a given set of classrooms with assured capacities, should be assigned. While solving this problem, they utilize the similarity between the examination-timetabling problem and examination-classroom-assignment. Kalender (2006-2007) constructed a model for exam timetabling problem in a Yeditepe University/ Computer Engineering Department. Hyper-heuristics were applied. Al-Yakoob et al. (2007) constructed a model for exam scheduling in Kuwait University. Mathematical programming was applied. They had intended minimize the total dissatisfaction and inequity costs associated with assigning proctors to exams. Sevkli et al. (2008) constructed a model for exam timetabling problem in a Fatih University Vocational School. They intended to minimize the number of conflicts. Another study about examination timetabling was carried out in United States Air Force Academy/West Point (USAFA) by Wang et al. (2010). In the USAFA, there are more than a hundred examinations to be held in an examination period and they emphasize that there is simply no feasible solution to that problem if it is not allowed to schedule any examination more than once. This necessity brings out the objective function which is to minimize the number of these duplicated examinations.

Acar (2010) constructed a model for exam timetabling problem in a Fatih University. A mathematical model and heuristic methods were applied. He intended to minimize the number of students who have more than one exam in the same timeslot and in the same day. Kalayci and Gungor (2010) concentrate on students' success model. Their initial objective is maximizing the time gap among examinations considering the difficulties of examinations. According to the researchers, difficult examinations require more studying and resting time than the easier ones. Altıntaş (2011) constructed a model for exam timetabling problem in a Süleyman Demirel University. Genetic Algorithms, Ant Colony Algorithm, Tabu Search, Simulated Annealing were applied. Gürel (2012) constructed a model for exam timetabling problem in the Maltepe University. Random Assignment Algorithm was applied. Köksalmış et al. (2014) developed a mathematical programming model to solve the examination timetabling problem for the Turkish Air Force Academy (TUAFA). In addition to common timetabling constraints such as conflict prevention and respecting classroom capacities, the problem involves a number of novel aspects. One entails spreading out cadets' exams appropriately to prevent fatigue. Another involves the difficult task of assigning exams of multiple year and discipline to the same room simultaneously according to seating plan policy in order to prevent cheating.

To our best knowledge, the studies in the literature deal with specific problems for specific institutions, which means that the developed models for these problems may differ in constraints, objective functions and decision variables from the problem addressed in this thesis. Therefore, any of the models developed in the literature cannot be applied directly to the İstanbul Bilgi University's problem. Furthermore, the problem, model and solutions obtained in this research can contribute to the timetabling literature for problems of similar nature.

3. Problem Definition

As mentioned earlier, this study aims to develop a mathematical model to assign the examinations of each department to the available timeslots at İstanbul Bilgi University Faculty of Engineering and Natural Sciences where there are over 1,000 students studying in the thirteen different departments of Computer Science, Industrial Engineering, Computer Engineering, Computer Engineering (Liverpool), Civil Engineering, Electrical-Electronics Engineering, Electrical-Electronics Engineering (Liverpool), Energy Systems Engineering, Genetics and Bioengineering, Mechanical Engineering, Mechatronics Engineering, Financial Mathematics, Mathematics. The numbers of the students and years in each department vary. Table 1 shows the number years and number of students studying in Industrial Engineering Department as of the Fall 2015 as a sample.

Table 1: Number of students in Industrial Engineering Department with respect to year

Year	1	2	3	4
Industrial Engineering Department	70	58	46	45

The curriculum is fixed for each department; for the 1st year, sample curriculums of some departments are provided in Table 2. The course numbers that are listed in the curriculum table are not the real ones used at İstanbul Bilgi University; they are generated in this study to simplify the work. Obviously this has no impact on the validity of the model or the results. İstanbul Bilgi University Faculty of Engineering and Natural Sciences has four-year academic programs (total of eight semesters) where each academic year is denoted as a year. Its education program is formatted according to the goals of the İstanbul Bilgi University while satisfying the standards and accreditation requirements for engineering by the Council of Higher Education.

Evaluation of students' academic success is primarily based on one midterm and one final examination for each course. Twice per semester there are approximately 120 examinations that must be held at Faculty of Engineering and Natural Sciences, requiring new timetables to be constructed on an ongoing basis. According to the yearly calendar, examinations have to be held in two weeks (10 Days) period. In each day, there are two sessions: morning and afternoon sessions. As a total, there are 20 timeslots available and each examination has to be held once in this period.

In addition to the basic timeslot constraints aforementioned, there are a number of important preferences and constraints to be taken into account. These are as follows:

- Examinations have to be held once during the examination period. Therefore, there will be no examinations left unscheduled at the end of the examination period.
- Students cannot have more than one examination in the same timeslot.
- Depending on the instructors' preferences, some examinations are preferred to be scheduled in the morning sessions if possible.
- Some lectures are common to two or more departments, as shown in Table 2. The examinations of these lectures have the same questions; therefore, they must be held in the same timeslot.
- Another limitation is related to the number of the examinations in consecutive timeslots. To be able to give students enough time to study between examinations, the number of examinations is set to be two in three consecutive timeslots.

Table 2: Sample curriculum in Fall 2015

Year	Course	Department						
		1	2	3	4	5	6	7
1	1	CMPE 100	CMPE 100	LCMPE 100	CMPE 130	LPHYS 100	ENGR 180	ESEN 101
	2	MATH 169	ENGR 180	LENGR 180	ENGR 180	LCMPE 100	CHEM 100	CHEM 100
	3	ENG/E 179	MATH 169	LMATH 169	MATH 169	LENGR 180	CMPE 130	ENGR 104
	4	TK 103	PHYS 100	LPHYS 100	PHYS 100	LMATH 169	MATH 169	MATH 169
	5		ENG/E 179	LENG/E 179	ENG/E 179	LENG/E 179	ENG/E 179	ENG/E 179
	6		TK 103	TK 103	TK 103	TK 103	TK 103	TK 103

1: Computer Science 2: Computer Engineering 3: Computer Engineering (Liverpool) 4: Electrical-Electronics Engineering 5: Electrical-Electronics Engineering (Liverpool) 6: Industrial Engineering 7: Energy Systems Engineering

4. Model Development

In this section we develop a mathematical model to assign the examinations of each department to the available timeslots. The primary objective of the model is to find a feasible solution.

Parameters;

Y = a set of y years where y = {1, 2, 3, 4};

D = a set of d departments where d = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13};

E_{yd} = a set of c examinations where c depends on the y year and d department;

T = a set of t timeslots where t = {1, 2,..., 20};

$$MOR_{ydc} = \begin{cases} 1, & if\ an\ exam\ c\ must\ be\ held\ in\ the\ morning\ session; \\ 0, & otherwise. \end{cases}$$

$Code_{ydc}$ =an integer number from 1 to 118

Decision Variables;

The following two decision variables are defined to be used in the model:

$$X_{ydct} = \begin{cases} 1, & if\ an\ exam\ e\ in\ rank\ r\ and\ department\ d\ is\ held\ in\ timeslot\ t; \\ 0, & otherwise. \end{cases}$$

$$A_t = \begin{cases} 1, & if\ there\ is\ at\ least\ one\ exam\ scheduled\ to\ timeslot\ t; \\ 0, & otherwise. \end{cases}$$

Constraints

Since the problem is a constraint satisfaction problem that does not optimize a specific criterion, the mathematical model does not have any objective function. Any feasible solution in the search space is acceptable as a final solution of this problem. The constraints for the problem at hand are formulated as follows:

$$\sum_{t} X_{ydct} = 1 \qquad t \in T, \quad y \in Y, \quad d \in D \quad \text{and} \quad c \in C_{yd} \tag{1}$$

$$\sum_{c} X_{ydct} \leq 1 \qquad c \in C_{yd}, \quad y \in Y, \quad d \in D \quad \text{and} \quad t \in T \tag{2}$$

$$\sum_{y}\sum_{d}\sum_{c} X_{ydct} \leq M.A_t \qquad y \in Y, \quad d \in D, \quad c \in C_{yd} \quad \text{and} \quad t \in T$$

$$\sum_{y}\sum_{d}\sum_{c} X_{ydct} \geq A_t$$

$$\sum_{t} A_t \leq \text{Max}(C_{yd}) \tag{3}$$

$$\sum_{g} X_{ydc(2g-1)} \geq MOR_{ydc} \qquad g \in 1..(\frac{T}{2}), \quad y \in Y, \quad d \in D \quad \text{and} \quad c \in C_{yd} \tag{4}$$

$$X_{ydct} + X_{ydc(t+1)} + X_{ydc(t+2)} + X_{ydc(t+3)} \leq 3 \qquad y \in Y, \quad d \in D, \quad c \in C_{yd} \quad \text{and} \quad t \in 1..7$$

$$X_{ydct} + X_{ydc(t+1)} + X_{ydc(t+2)} + X_{ydc(t+3)} \leq 3 \qquad y \in Y, \quad d \in D, \quad c \in C_{yd} \quad \text{and} \quad t \in 11..17 \tag{5}$$

$$\sum_{c} X_{ydct} \leq \lceil \left(\frac{C_{yd}}{2}\right) \rceil \qquad c \in C_{yd}, \quad y \in Y - \{1\}, \quad d \in D \quad \text{and} \quad t \in 1..10$$

$$\sum_{c} X_{ydct} \leq \lceil \left(\frac{C_{yd}}{2}\right) \rceil \qquad c \in C_{yd}, \quad y \in Y - \{1\}, \quad d \in D \quad \text{and} \quad t \in 11..20 \tag{6}$$

$$|Code_{y_1 d_1 c_1} - Code_{y_2 d_2 c_2}| \geq |X_{y_1 d_1 c_1 t} - X_{y_2 d_2 c_2 t}| \qquad y_{1,2} \in Y, \ d_{1,2} \in D, \ c_1 \in C_{y_1 d_1}, \ c_2 \in C_{y_2 d_2} \text{ and } t \in T \tag{7}$$

The constraints can be explained as follows:

(1) The first set of constraints guarantees that any examination in the set of C_{yd}, which is the examinations of year y and department d, has to be held exactly once in the examination period. Therefore, there will not be any examinations left unscheduled at the end of the period and there will not be a need for make-up examinations or any extension in the time period. This is a hard constraint and, therefore, it cannot be violated in any case.

(2) This set of constraints guarantees that each student in year y and department d may has at most one examination in any examination session. In other words, examinations which are assigned for specific student groups cannot overlap. This constraint is known as “conflict constraint” in the literature and it is a hard constraint as well.

(3) Total number of sessions occupied must be at most the maximum number of examinations taken by a student.

(4) Some examination must be held in the morning sessions.

(5) With these constraints, it is guaranteed that the maximum number of examinations in four consecutive examination sessions is at most three. This way, students have time to study between examinations and the distribution of the examination over the examination period will be smoother.

(6) Examinations in a weekly period do not exceed half of the maximum number of examinations taken by a student.

(7) Some courses are common among different departments, and examinations with common questions must be held at the same session.

5. Results and Conclusions

The model in Section 4 is implemented in IBM ILOG CP Optimizer. A high–performance computer, with Intel ® Core ™ i7-6500 CPU @ 2.50 GHz processor with an 8.00 GB of installed memory, is used to solve the model. Fall semester data of 2015 are used as input data. CP optimizer finds a feasible solution within 3 seconds by using 8015 constraints and 12500 decision variables. Values of the decision variables are exported to MS Excel 2016 to create an examination timetable; as an illustration purpose sample examination timetable for the 1st year students at İstanbul Bilgi University Faculty of Engineering and Natural Sciences is presented in Table 3.

Table 3: Sample examination timetable

		Department						
Periods		1	2	3	4	5	6	7
Monday	Morning		ENGR 180		ENGR 180		ENGR 180	ESEN 101
	Afternoon							
Tuesday	Morning			LENG/E 179		LENG/E 179		
	Afternoon	MATH 169	MATH 169		MATH 169		MATH 169	MATH 169
Wednesday	Morning			LPHYS 100		LPHYS 100		
	Afternoon	ENG/E 179	ENG/E 179		ENG/E 179		ENG/E 179	ENG/E 179
Thursday	Morning		PHYS 100	LENGR 180	PHYS 100	LENGR 180		
	Afternoon	TK 103	TK 103	TK 103	TK 103	TK 103	TK 103	TK 103
Friday	Morning	CMPE 100	CMPE 100				CHEM 100	CHEM 100
	Afternoon			LMATH 169		LMATH 169		
Saturday	Morning							
	Afternoon			LCMPE 100	CMPE 130	LCMPE 100	CMPE 130	ENGR 104

1: Computer Science 2: Computer Engineering 3: Computer Engineering (Liverpool) 4: Electrical-Electronics Engineering 5: Electrical-Electronics Engineering (Liverpool) 6: Industrial Engineering 7: Energy Systems Engineering

As was mentioned earlier, there is not a general model that is applicable to all timetabling problems and there are not general data which can be used to verify the models in the literature to the author's best knowledge. Therefore, the verification of the model is carried out by running the model with different examination periods.

In this study, a constraint programming model is developed to solve the examination timetabling problem at İstanbul Bilgi University. To our best knowledge, the studies in the literature deal with specific problems for specific institutions, which means that the developed models for these problems may differ in constraints, objective functions and decision variables from the problem addressed in this thesis. Therefore, any of the models developed in the literature cannot be applied directly to the İstanbul Bilgi University problem which resulted in the need to develop and employ new models. Since there are no general data in the literature to verify the model, the verification was done by trying different instances of the problem and the results of these instances were compared. As a next step, assignment of exams to classrooms, proctors to classrooms will be conducted. Moreover, model will be extended by maximizing classroom utilization which will simultaneously reduce the number of proctors needed as well as the total number of timeslots required.

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The Effects of Knowledge Sharing and Types of Learning on Individual Creativity: A Structural Equation Model

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Abstract

This study develops a structural equation model to examine the effects of knowledge sharing and learning types (i.e. exploration and exploitation) on individual creativity. The analysis aims to address the following research questions: (i) Can organizations improve their employees' individual creativity by encouraging knowledge sharing behavior? (ii) Can employees improve their individual creativity by refining and extending their existing competencies or pursuing and acquiring new knowledge? All hypothesized relationships except the one between exploitation and individual creativity are supported in the estimated structural model.

Keywords

Individual Creativity, Knowledge Sharing, Learning Types, Structural Equation Modelling (SEM)

1. Introduction

In today's dynamic and intense competitive business environment, organizations that desire to enhance their ability to recognize the value of new information, apply it to commercial ends and to improve their performance, should give importance to individual creativity. As Chae et al. (2015) mentioned it in their study, many researchers and practitioners paid attention to individual creativity because of its contribution to organizational competiveness. Creativity can be defined as the creation of new and useful ideas on products, services or procedures for organizations, which should be designed as a collective work of individuals working together. In this process, knowledge, interaction between individuals and personal characteristics play a key role.

According to the results of the literature review, the two most important concepts affecting individual creativity are "knowledge sharing" and "learning types". In order to be creative, individuals should primarily increase their knowledge for generating useful ideas and solving problems. This requires knowledge sharing, which forms a mechanism that helps to develop social interactions that might provide individuals with useful resources for their own innovations, and allows to make collaborative knowledge flows more effective to facilitate individuals to acquire new information and stimuli for exploring external ideas and exploiting internal knowledge (Radaelli et al., 2014). Type of learning is another critical mechanism to increase creativity, which consists of two sub-factors: exploration and exploitation. Exploration refers to learning gained through processes of concerted variation, planned experimentation, and play, whereas exploitation refers to learning gained via local search, experiential refinement, and selection and reuse of existing routines (Baum et al., 2000). Briefly, the essence of exploitation is the refinement and extension of existing competencies, technologies, and paradigms and the essence of exploration is experimentation with new alternatives (March, 1991).

2. Theoretical Background and Hypotheses

2.1. Knowledge Sharing and Individual Creativity

The creativity concept received considerable attention across a variety of disciplines, ranging from sociology to organizational behavior. Because of this, there are several definitions of creativity based on different perspectives. Some researchers define creativity based on personal characteristics, some on the product, and others on the process itself (Amabile, 1988). In her study, Amabile (1988) describes creativity, based on the product-oriented view, as the production of novel and useful ideas by an individual or small groups of individuals working together. Mumford et al., (2012) state in their study that creativity is not simply a matter of idea production, although this may have an important influence on creativity, it is rather the production of high quality, original, and elegant solutions to problems with the performance view. In this study, creativity is characterized as creation of new and useful ideas on products, services or procedures for organizations, which should be designed as a collective work of individuals working together.

According to the interactionist perspective, creativity is a complex interaction between the individual and his or her work situation at different levels of organization and it is affected by antecedent conditions (e.g., biographical variables), cognitive style and ability (e.g., divergent thinking), personality (e.g., self-esteem), relevant knowledge, motivation, social influences (e.g., rewards), and contextual influences (e.g., physical environment) (Anderson et al., 2014). Although knowledge is a key component for creativity (Amabile, 1996), empirical studies on how knowledge affects employee creativity and innovation in the workplace are rather rare (Anderson et al., 2014). Individuals who want to undertake creative works, must not only constantly manage knowledge, and in particular elaborate, recombine, translate and disseminate tacit knowledge, but also coordinate and integrate different sets of knowledge with other individuals or teams (Radaelli et al., 2014). Knowledge sharing enables social interactions that might provide individuals with useful resources for their own creative works. Employees' positions in their social networks is known to affect their creativity (Anderson et al., 2014). Thus, the following hypothesis is proposed:

H1: Employees' Knowledge Sharing behavior positively influences Individual Creativity.

2.2. Learning Types and Individual Creativity

As mentioned in the introduction, two types of learning are distinguished: exploitation and exploration. There is still considerable ambiguity in the literature concerning the meanings and relationship of these concepts. Vermeulen & Barkema (2001) defines exploitation briefly as the "ongoing use of a firm's knowledge base" to generate new principles and exploration as the "search for new knowledge". Exploitation is related to terms such as refinement, efficiency, selection, and implementation, while exploration to such terms as search, variation, risk taking, discovery, and innovation (March, 1991).

Typically, exploitation is more rapidly improved than exploration, which makes it an important factor influencing the search for new knowledge (March, 1991). Accumulated experiences (based on exploitation) lead individuals to develop new knowledge, which, according to the theory of individual creative action, is one of the critical enablers of creative action (Ford, 1996). Based on these arguments, the following is hypothesized:

H2: Exploitation positively influences Exploration.

Exploitation of existing knowledge is important for individual creativity because its main role is producing new solutions and perspectives (Schumpeter, 1934 cited by Katila & Ahuja, 2002). Accordingly, the following hypothesis is formulated:

H3: Exploitation positively influences Individual Creativity.

Exploration is useful for understanding the creative process, because it is associated with past success to explore new ideas (Audia & Goncalo, 2006). Exploration has a breaking way owing to reflection of efforts, thoughts and passing the different directions to increase creative ideas (March, 1991). Thus, the following hypothesis is proposed:

H4: Exploration positively influences Individual Creativity.

2.3. Knowledge Sharing and Learning Types

Knowledge sharing behavior is defined as the varied ways in which team members exchange and discuss knowledge with internal or external teams, such as face-to-face discussions, informal and formal networks, and best practices (Chae et al., 2015). Exploitation activities of managers include using and refining their knowledge. It is clear that knowledge sharing provides the opportunity to capture existing knowledge and, thereby, to improve the exploitation process. Thus, the following hypothesis is proposed:

H5: Employees' knowledge sharing behavior positively influences Exploitation.

3. Research Methodology

The conceptual framework proposed in this study, which is given in Figure 1, was constructed based on a comprehensive review of literature. In order to test the five hypotheses developed in the framework, the relevant factors (i.e., knowledge sharing, exploitation, exploration and individual creativity) were measured using multiple-item scales that were adapted from previous studies. In this context, firstly, a structured questionnaire, including a total of 23 questions to operationalize the factors in the framework was designed. The questionnaire was organized as expressions to be answered by the respondents, using a 7-point Likert scale, ranging from strongly disagree to strongly agree. The final version of the questionnaire was obtained according to the experts' opinions and a pilot study to ensure content validity and was sent to a random sample through social networks that allowed authors to spread the questionnaire to a wide range of participants. Consequently, a total of 203 respondents provided usable responses to the questionnaire, where each of them had a working experience more than six months. The empirical data obtained were analyzed using Structural Equation Modeling (SEM) approach with LISREL 8.54 software to test the hypothesized relationships among the relevant factors. Maximum Likelihood (ML) estimation method was used for measurement and structural model assessment.

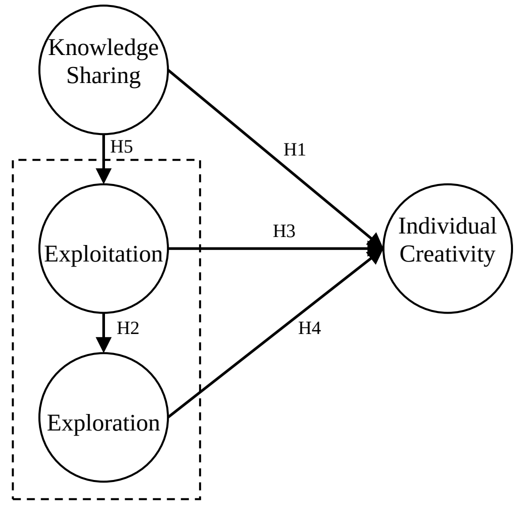

Figure 1. Proposed Conceptual Framework

4. Data Analysis and Results

The subjects in the study comprised of 34.7% female and 65.3% male. The majority (50.7%) of them were in the age group of 18-25 years, 35.46% of them in the age-group of 26-35 years, 11.82% of them in the age group of 36-45 years, and only 1.97% of them were 46 or above. The majority of the respondents' educational background was Bachelor's degree (55.66%) followed by Master's degree (34.48%). 62.56% of the respondents had a working experience of 6 months to 3 years, 16.25% of them 4 to 6 years and 21.18% of them over 7 years.

Throughout the analysis, model adequacy was assessed by reviewing the model fitting indices suggested by Hair, et al. (1998), Jöreskog & Sörbom (1996) and Hooper, et al. (2008). Firstly, the measurement model was assessed by the size of factor loadings of Knowledge Sharing (PAY), Individual Creativity (BY), Exploitation (KUL) and Exploration (KES) constructs. According to Hooper et al. (2008), convergent validity of the measurement model should be supported by item reliability, composite reliability (CR) and average variance extracted (AVE). Based on the results, four of the eight items reflecting the Knowledge Sharing construct were removed from the analysis due to high measurement errors, so that the revised model contained a total of 19 items.

Table 1 shows that standardized factor loadings of each item are greater than 0.50 and their t-values are statistically significant ($p < 0.01$). CR estimates range from 0.70 to 0.74 exceeding the threshold level of 0.7 and AVE values of each construct range between 0.49 and 0.55 indicating a satisfactory estimation. Consequently, it can be said that the measurement models have an acceptable fit with the collected data and it is reliable to test the structural relationships among the constructs.

Table 1: Convergent Validity of the Measurement Model

Constructs	Items	Standardized Factor Loadings	t values	Composite Reliability (CR)	Average Variance Extracted (AVE)
Knowledge Sharing Behavior (PAY)	PAY1	0.79	-	0.70	0.49
	PAY3	0.73	10.86		
	PAY5	0.70	10.31		
	PAY7	0.55	7.80		
Individual Creativity (BY)	BY1	0.76	-	0.74	0.55
	BY2	0.76	10.98		
	BY3	0.66	9.33		
	BY4	0.79	11.49		
	BY5	0.76	11.00		
Exploitation (KUL)	KUL1	0.74	-	0.74	0.55
	KUL2	0.56	7.77		
	KUL3	0.73	10.37		
	KUL4	0.84	12.17		
	KUL5	0.76	10.86		
Exploration (KES)	KES1	0.67	-	0.70	0.49
	KES2	0.85	10.59		
	KES3	0.59	7.66		
	KES4	0.68	8.72		
	KES5	0.68	8.73		

Following the assessment of the measurement models, fit indices of the structural model are summarized in Table 2. The chi-square value assesses the magnitude of discrepancy between the sample and fitted covariance matrices and should be insignificant (Hooper, et al., 2008). The chi-square value was significant for the proposed model (χ^2 = 321.6, df = 147, p < 0.001), traditionally indicating a lack of model fit. However, as the chi-square statistic is known to be sensitive to sample size (Hooper, et al., 2008) and assumes normality, it can result in the rejection of a model that appears to fit the data quite well. Therefore, other goodness-of-fit measures should be considered in SEM. Due to the restrictiveness of the chi-square statistic, the normed chi-square statistic (i.e. χ^2 /df) has been recommended as a better goodness of fit measure, where values of less than 3 has been suggested to indicate a reasonable fit to the data (Bollen, 1989). The normed chi-square value of the proposed model is 2.18 (i.e. 321.16/147) indicating an acceptable fit. Some of the other goodness-of-fit measure values are as follows: RMR=0.96, SMRM=0.0554, RMSEA=0.077, GFI=0.86, AGFI=0.81, NFI=0.96, NNFI=0.98 and CFI=0.98 (See Table 2). According to these results, it can be concluded that the overall model shows adequate fit.

The resulting standardized parameter estimates of the proposed model can be seen in Fig. 2. Totally, four out of the five hypotheses are supported (See Table 3). The parameter estimates of structural relations indicate that Knowledge Sharing Behavior significantly affects both Individual Creativity and Exploration factors (γ_1=0.73, t-value=2.54 and γ_2=0.93, t-value=10.09, respectively). Regarding the hypotheses 2 and 3, Exploitation factor significantly affects Exploration factor (β_1=0.91, t-value=8.96) but it does not have any influence on Individual Creativity (γ_3=-0.63, t-value=-1.66) in opposition to the expectations. As mentioned in previous section, exploitation includes use of a firm's knowledge base whereas exploration includes search for new knowledge and is related to terms such as search, variation, risk taking, discovery and innovation. That might be the reason for the relevant unsupported hypothesis. Therefore, the insignificant relationship between Exploitation and Individual Creativity factors might be examined in detail by reviewing the literature again. Finally, according to the results, Exploration significantly affects Individual Creativity (β_2=0.84, t-value=3.60).

Table 2. Goodness-of-Fit Statistics of Structural Model

Fit Indices	**SEM Results**	**Suggested Value**
Root Mean Square Residual (RMR)	0.096	Should be close to 0
Standardized Root Mean Square Residual (SRMR)	0.054	0.05 < SRMR ≤ 0.08
The Root Mean Square error of Approximation (RMSEA)	0.077	0.05 < RMSEA ≤ 0.10 (Schermelleh-Engel et al., 2003)
Goodness of Fit Index (GFI)	0.86	GFI ≥ 0.90 (Jöreskog & Sörborn, 1996)
Adjusted Goodness of Fit Index (AGFI)	0.81	AGFI ≥ 0.90 (Jöreskog & Sörborn, 1996)
Normed Fit Index(NFI)	0.96	NFI ≥ 0.90 (Schermelleh-Engel et al., 2003)
Non-normed Fit Index (NNFI)	0.98	NNFI ≥ 0.90 (Kelloway, 1998)
Comparative Fit Index (CFI)	0.98	CFI ≥ 0.90 (Kelloway, 1998)

Table 3. Results of Hypotheses

Hypotheses	**Results**
H1: Employees' Knowledge Sharing behavior positively influences Individual Creativity.	Supported
H2: Exploitation positively influences Exploration.	Supported
H3: Exploitation positively influences Individual Creativity.	Unsupported
H4: Exploration positively influences Individual Creativity.	Supported
H5: Employees' knowledge sharing behavior positively influences Exploitation.	Supported

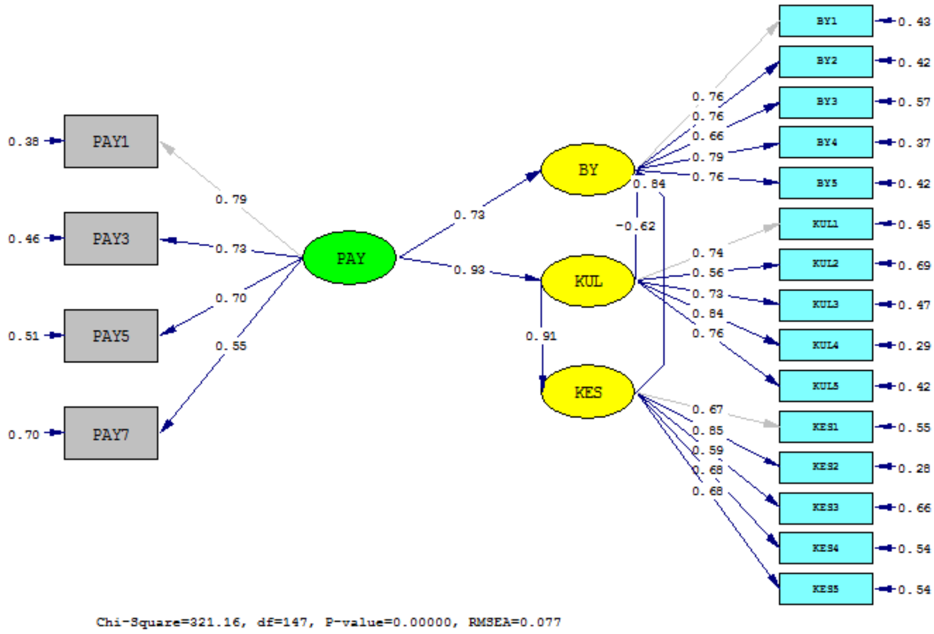

Figure 2. Path Diagram of the Proposed Framework (Standardized Values)

5. Conclusion

In this study, in order to explore the effect of knowledge sharing and learning types (i.e. exploration and exploitation) on individual creativity a structural equation model had been constructed based on a comprehensive review of literature. A structured questionnaire, including a total of 23 questions to operationalize the factors in the framework was designed and sent to a random sample through social networks. A total of 203 respondents provided usable responses to the questionnaire. These responses were analyzed using SEM approach with LISREL 8.54 software to test the hypothesized relationships. The results of the analyses indicate that organizations can improve their employees' individual creativity by creating a knowledge sharing climate and employees can improve their individual creativity by pursuing and acquiring new knowledge

instead of refining and extending their existing competencies. As individual creativity is vital for organizational success and longevity, managers must promote knowledge sharing within their organizations.
As a further research, in order to support the conceptual model, the relationships proposed in the framework can tested with a larger sample and applied in different sectors in order to reveal sector-specific differences.

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Proceedings of the Global Conference on Healthcare Systems Engineering and Management 2016, Istanbul, Turkey, July 14-15, 2016

A Computer-Aided Grading System for Clinical Evaluation of Dry Eye Syndrome

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Abstract

Today, Dry Eye Syndrome (DES) is a widely seen health problem that is disorder of the tear film due to tear deficiency. The number of dry punctate dots (N_{dots}) appear on corneal surface can be used as diagnostic indicator of DES severity. Well-trained ophthalmologists can evaluate corneal conditions at the end of physical examination in which many tough and time-consuming tests are applied to patient. Taking into account that current methods are subjective, the enhancement of diagnosis techniques would significantly contribute to clinical DES analysis. Computer-aided diagnosis systems concerning of this common disease that provide more objective and reliable results would be beneficial for use in clinics. Implementation of an automated system by utilizing image processing techniques can be used in decision making, also speed up evaluation and treatment processes. Experimental studies are conducted on a clinical data set of fluorescein-stained eye images labeled based on clinical Oxford grading scale 0 to 4, and when automated score and clinical score are compared it can be indicated that Pearson's correlation between them is 0.981; Lin's Concordance Correlation Coefficients (CCC) is 0.980, 95% confidence interval (0.963–0.989). The automated predicted grade (G_{pred}) is estimated from regression fit to be: $G_{pred} = 1.3244 \log(N_{dots}) - 0.0612$. It is clearly seen that successful automatic DES diagnostic kits can be developed by working on the fluorescein-stained cornea images and implementing computational techniques to assist investigators for a more objective and faster DES diagnosis in real life.

Keywords

Dry eye, Oxford grading scale, image processing, fluorescein staining, corneal images

1. Introduction

The eye is the crucial sense organ of the sight that transforms the light energy into electrical signals and sends to the brain via the optic nerve. The cornea is a transparent localised in front of the eye for the purpose of assist to focus incoming light. The corneal epithelium cells are needed to keep moist to remain healthy. This requirement is fulfilled by tear film layer of lubricating corneal surface.

The tear film has several differing functions such as lubrication, visual, cleaning, nutritive and antimicrobial function (Sullivan et al., 2002). The tear film has three main components as seen in Figure 1: lipid layer (has a major role), aqueous layer, mucin layer that provide tear film stabilization, protection from evaporation, electrostatic attraction, optimal spreading and improved ocular absorption (Lin et al., 2014).

Today, dry eye syndrome (DES) is one of the widely seen eye health problem that is a disorder of the tear film due to lack of tear production or excessive tear evaporation. DES is associated with symptoms of serious ocular discomforts (Asbell et al., 2006). It is accompanied by increased concentration of the solution of the tear film and inflammation of the ocular surface (Lin et al., 2014). In (Foulks et al., 2007), DES defined as: "DES is a multifactorial disease of the tears and ocular surface that results in symptoms of discomfort, (Begley et al., 2003; Adatia et al., 2004; Vitale et al., 2004) visual disturbance, (Liu et al., 1999; Goto et al., 2002) and tear film instability (Bron, 2001; Goto et al., 2003) with potential damage to the ocular surface. It is accompanied by increased osmolarity of the tear film (Gilbard, 1994; Murube, 2006; Tomlinson et al., 2006) and inflammation of the ocular surface (Tsubota et al., 1999).

Figure 1: Trilaminar structure of the tear film composed by a lipid, aqueous and mucous layer (Eddie et al., 2014)

Epidemiological studies indicate that DES affecting millions of people around the world is a growing public health problem and the prevalence of this syndrome in Turkey is ranged from 10% to 25% according to 45% of ophthalmologists and 25% to 50% according to 25% of ophthalmologists who joined to these studies. Several factors, such as age, adverse environmental conditions, use of certain medications, or visual tasks that reduce blink rate, have contributed to that increment (Fenga, et al., 2008).

In clinical evaluation, many tough and time-consuming clinical tests are applied to patient for diagnosis of DES. Evaluation of cornea structure and dysfunctions depends on ability and experience of ophthalmologists. DES severity can be measured based on subjective or objective evaluation. Subjective evaluation depending on visual symptoms cannot ensure consistency because the symptoms and histories of dry eye patients are widely variable (Penny et al., 2006). Objective evaluation consists of some traditional tests such as Schirmer test, lacrimal river width, tear fern test. Ocular surface and inflammation can be evaluated conjunctival and corneal staining, Meibomian gland evaluation, tear break-up tests or other tests (Lin et al., 2014).

An ideal diagnostic technique should be preferably non-invasive, objective, reproducible and sustainable in terms of time and cost. More objective measurement techniques are required for diagnosis of such a common disease. Corneal and conjunctival staining enable the evaluation of ocular surface damage by instilling a dye such as sodium fluorescein, rose bengal or lissamine green. Sodium fluorescein is a vital dye that has no intrinsic toxity. When fluorescein staining is used, staining must be graded as quickly as possible after instillation, since the dye then diffuses rapidly into the tissue and its high luminosity blurring the stain margin (Foulks et al., 2007). Although this technique can provide satisfactory diagnosis results, some reasons such as imaging quality and timing problem restrict the ophthalmologists in clinical application.

Sodium fluorescein dye is used with the aim of biomicroscopic observation of corneal epithelium to assess staining of corneal epithelial defects. The corneal fluorescein staining pattern is observed through a slit lamp microscopy under a cobalt blue filter (Figure 2 (left)). The presence of corneal epithelium damage can be observed as punctated dots and areas (Figure 2 (right)). Clinical grade of staining of greater than grade 1 are considered as abnormal (Bron et al, 1997).

Figure 2: Biomicroscopic examination with a slit lamp on the left (Eddie et al., 2014); dryness appearance of fluorescein-stained cornea under cobalt blue filter on the right

Related work: Regarding computer-assisted implementation of various clinical tests to diagnose DES automatically, some attempts are found in the literature: There are various techniques used to measure in an objective way DES based on the lipid layer thickness via sophisticated optic system (King-Smith et al., 1999) and an interference camera analzing interference colors (Goto et al., 2003). Computer-aided assessment of interference patterns of the tear film lipid layer was initially proposed in (Remeseiro et al., 2011; Remeseiro et al., 2014) to diagnose DES automatically, and then improved in (Remeseiro et al., 2015). Taking into account thinner lipid layer speeds up water evaporation, the evaluation of lipid layer thickness would contribute to clinical DES analysis. CASDES, an useful computer-aided was implemented to give information eye practitioners by providing tear film maps system based on color-texture analysis. Texture based feature extraction; correlation based feature selection and Support Vector Machine (SVM) based classification were implemented on VOPTICAL tear film dataset labeled according to interference pattern. An automatic tool to compute the BUT by analyzing tear film videos was proposed in (Ramos et al., 2014). Development of an automated method of fluorescein staining grading based on evaluation of superficial punctate keratitis was proposed by using fluorescein-stained corneal image dataset (Rodriguez et al., 2015). Oxford grading scale which is the famous one of the clinical evaluation techniques was aimed to automate in this study. At the end of the study, it has been shown that health-care professionals may prefer to use an automated grading system depending on contribution of its use to clinical trials and their performance. A recently used technique evaluation of infrared thermography values in DES patients (Acharya et al., 2015). The features were extracted from Higher Order Spectra(HOS) and ranked using t-test ranking strategy. Various classifiers such as K-Nearest Neighbor (KNN), Decision Tree (DT), SVM and Naïve Bayesian Classifier (NBC) were proposed to be able to identify the dry eye and normal classes automatically with a high classification accuracy.

Our work: Advanced image processing skills present a promising way for the evaluation of ocular surface and grading DES by processing images of the staining pattern. An automated grading and diagnosis system of DES can be implemented to use efficiently in real life. In this study, we aim to develop a computerized diagnosis system based on image processing techniques and Oxford grading schema at the region of interest (ROI) level. The proposed methodology aims to make a specific ROI definition and then region-level dry eye analysis. The dry eye spots appearing on corneal surface can be used as diagnostic indicator of DES severity. Well-trained ophthalmologists can evaluate corneal conditions at the end of a physical examination. A number of time-consuming tests and examination regiments are applied to patient in order to diagnose DES in clinical settings. In addition to being time and resource intensive, current methods are also very subjective and dependent entirely on the perception of the ophthalmologists. Therefore automated, nonintrusive diagnosis techniques would greatly contribute to the clinical DES analysis. Computer-aided systems can potentially provide more objective and reliable results which would also benefit as remote diagnosis systems in distant places where there may not be well-trained ophthalmologists and modern testing techniques. A computerized diagnosis system (by utilizing novel image processing techniques) can be developed and used in clinical decision making, and then can also speed up evaluation, diagnosis and treatment procedures.

The paper is organized in the following manner: Section 2 describes briefly the data set of the fluorescein-stained corneal images employed in the conducted research and also provides detailed information regarding the methods used in this study. Section 3 presents the experimental study carried out in the study, the evaluation procedures used and the experimental results obtained. Finally, Section 4 describes the results and conclusion accessed from the study and some ideas intended for future work.

2. Materials and Methods

ROI is a selected special-purpose subset from a dataset. Accurate determination of ROI has high priority for the algorithm to be applied in the diagnosis of dry eye disease. Computer-assisted detection and extraction of ROI can be implemented on dry eye data taken after applying clinical fluorescein staining test. Taking into account that clinical diagnosis is made at ROI level in clinical applications, computerized segmentation of ROI would be helpful to speed up and enhance this process as first stage of a diagnostic system. The next step is to normalize the ROI in order to prevent possible imaging errors like flash artefacts. The last step is development of automated version of clinical grading system by implementing connected-component labeling algorithm.

2.1 Dataset

Dry eye images used in this study were gathered from the Keratoconus Center of Yıldırım Beyazıt University Atatürk Training and Research Hospital and data collection process continues for future studies. These images were recorded by Topcon DC-3 Integrated Camera Attachment that is a professional system for superb slit lamp photography in the year 2016. All the images taken were exported to *jpeg* format with an image size of 3264 × 2448 pixels using post-processing software installed with the camera IMAGEnet i-base and all of them were in RGB format. The data set consists of 40 data labeled by an ophthalmologist based on Oxford grading scale. Images that have clear visibility of staining were required (Figure 3 (right)), then images failing this criterion were eliminated (Figure 3 (left)). Before data collection, subjects were asked to relax for several minutes. During data acquisition process, subjects were not allowed to blink a few seconds before taking photographs. Some important points such as wearing contact lens, current eye disease, history of serious eye disease or general health were specially examined before photography to eliminate participants.

2.2 Conduct of Test

When sodium fluorescein is used, staining must be graded as quickly as possible after instillation, because of diffusion the dye rapidly into the tissue (Bron et al., 2003). Sodium fluorescein dye is instilled on the ocular surface. Slit-lamp is set 16 magnification with x10 oculars. Unquantified instillation is a convenient approach in clinical application using the following method (Bron et al., 2003):

- A single drop of unit dose saline is instilled onto a fluorescein-impregnated strip.
- When the drop is saturated, the excess is shaken into a waste bin with a sharp flick.
- The right lower lid is then pulled down and the strip is tapped onto the lower tarsal conjunctiva.

Punctate staining blurs are occurred after a short period diffusion of the fluorescein dye rapidly into the tissue. Therefore, observation and evaluation staining rapidly are essential in both of the right and then the left eye. If it is intended to photograph the staining pattern for grading, photography should follow immediately after each instillation (Foulks et al., 2007). If these processes are delayed, fluorescein staining may result in blurred pattern.

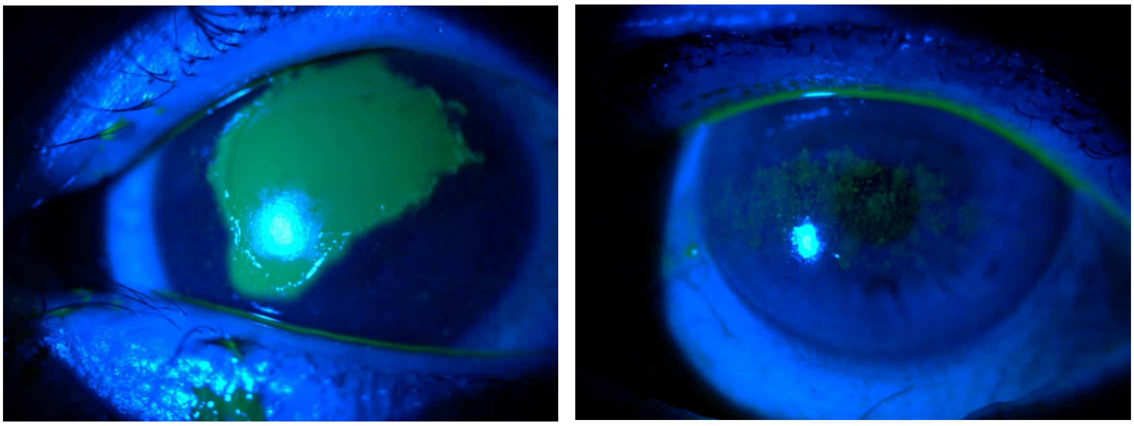


Figure 3: An eliminated sample from clinic dataset because of having an another epithelium defect on left; An used dry eye sample from clinic dataset has punctate dots on right

2.3 Image Capture Technique

Staining is graded right after instillation of sodium fluorescein solution into the inferior conjunctival tissues of both eyes of each subject. To guarantee proper distribution of the dye throughout the tear film surface, the subject blinks several times. Then, the specialist does not apply any cleaning processes before taking of corneal images. In this study, the corneal images are taken through a 8megapixel digital camera slit lamp system. Cobalt blue filter is used to optimize visibility of occurred punctate dots. All images are captured in RGB format. Camera parameters are fixed for all subjects.

2.4 Clinical Grading System

After data collection process is completed, all images are labelled based on the traditionally Oxford grading schema currently used in clinics by ophthalmologists in testing and evaluation stage. The schema is used to estimate amount of ocular surface damage in dry eye by grading with standard charts. Staining is represented by the total numbers of punctate dots of a series of grades that range from 0 none to 5 severe (Figure 4).

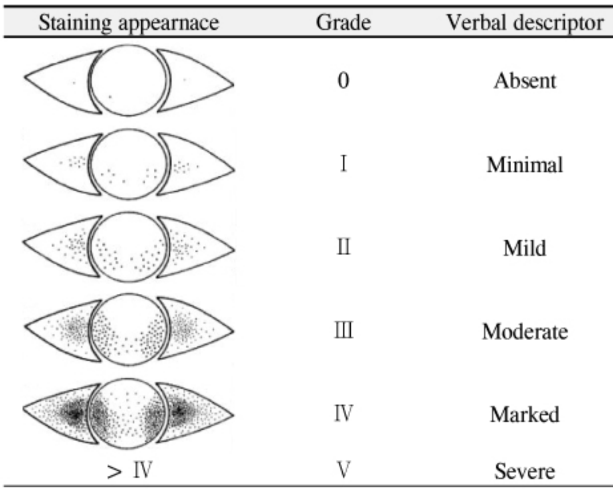
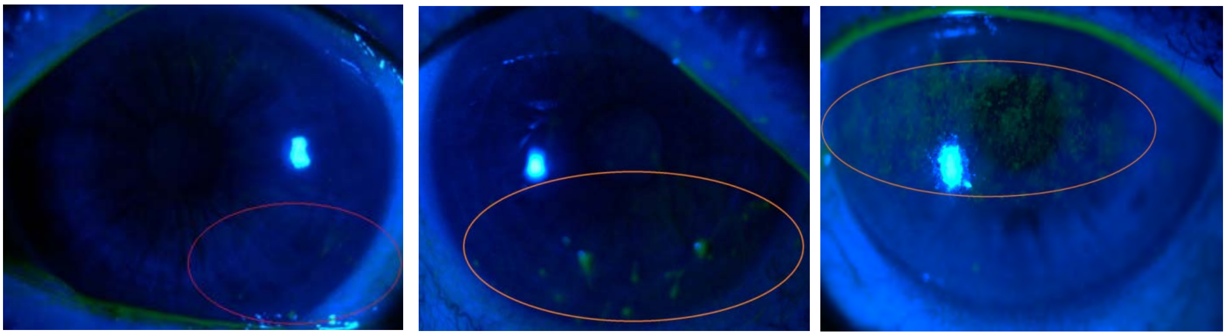


Figure 4: Oxford Grading Schema (Bron et al., 2003)

The total count of all dry areas and mean intensity, size of the area, perimeter, centroid, diameter information of each dry blob can not be evaluated objectively in clinical method. It is aimed that this grading system can be automated by utilizing computational image processing methods. Clinical grading system firstly focuses on inferior region to diagnose DES. In implemented study, user of program can select region to analyze location-independently (Figure 5).



A **B** **C**

Figure 5: Clinical grading of fluorescein staining patterns, A: grade 1, B: grade 2, C: grade 3.

2.4 Automated Grading System

Connected-component labeling; is an algorithmic implementation of graph theory, where subsets of connected components are uniquely labeled and is used to detect connected regions in binary digital images. To implement this approach on color images in higher dimensions, they need firstly to be processed.

Extraction of dry blobs is performed on binary images obtained from thresholding phase. After the implementation, blobs can be counted, filtered, and segmented. The connected component concept is described in terms of a path, and then specification of path based on component adjacency graph. The nature of a connected component depends on form of adjacency which one is chosen, 4- adjacency and 8-adjacency are the most common. 8-adjacency is selected in the conducted study.

The component adjacency graph whose vertices represent the connected components identified locally. Next, unique labels are assigned to each of their connected components. This can be as simple as assigning to each connected component a label derived from the smallest vertex label contained in the connected component

(Iverson, 2015). The pixels in each different connected component are assigned a unique integer, from 1 to the total count of connected components. The pixels labeled 1 belong to the first connected component; the pixels labeled 2 belong to the second connected component; and so on, and. On the other hand, background pixels are labeled 0 (Gonzales et al., 2009).

2.4 Statistical Methods

The pairwise correlations among the ophthalmologist is first determined using Pearson's correlation coefficient that provides information regarding correlation. The primary analysis is a comparison of the ophthalmologist-graded score to the automated-graded score. An estimator for the predicted score was derived by linear regression fit to ophthalmologist scores against the automated score. Using the results of this analysis, the best approximation to the clinical score may be written as follows:

$$G_{pred} = C_1 \log(N_{dots}) + \ C, \tag{1}$$

where G_{pred} is the automated predicted DES grade and N_{dots} is the computed punctate dot number.

3. Experimental Study

In general, inferior region has primary importance to analyze DES severity. In the implementation part of this study, a computerized location-independently DES diagnosis system was implemented at the ROI level by applying computational methods on fluorescein-stained corneal images. Image processing skills were needed for analysing and grading of these digital fluorescein-stained corneal images.

In the data acquisition process sodium fluorescein staining was applied to DES patients by ophthalmologists. Fluorescein-stained corneal images were gathered via slit lamp photography after instillation of sodium fluorescein solution into the conjunctival tissues of both eyes of each subject.

The first step of the computerized analysis is the segmentation of ROI from the remainder of the fluorescein-stained corneal image. Therefore, the user of the computer-assisted system firstly defines the ROI as a geometrically defined area of the cornea. Then, the image is automatically cropped based on the selected ROI and processed to remove artefacts. The next step; connected components labeling; is detecting individual dry blobs by analyzing which pixels are connected to each other. Each group of connected pixels, so each dry area will be given a label to identify it, so we can make measurements of each one. To visually show the user the distinct dry regions, a different color is assigned each region and the borders of them are drawn. The total count of all dry areas and mean intensity, size of the area, perimeter, centroid, diameter information of each dry blob are reported at the end of computational methods. According to list of the blobs, it can be said that the ophthalmologists can see a detailed quantitative analysis of DES.

3.1 Selection of Region of Interest

DES analysis techniques are implemented at the ROI level. The first step of the experimental study is the segmentation of ROI portion from the original image. Geometric parameters such as corneal diameter, eyelid shape could have variations among patients, therefore the first step cannot be exactly automated. Rectangular points are selected on image and this portion is cropped from the original image automatically.

3.2 Calculation of Punctate Dot Number

The next step of experimental study is processing RGB images to isolate ROI from the blue and red channels and analyze the green channel. After extraction of the green channel, image normalization process with background smoothing is implemented. Image brightness is normalized to remove flash artefacts due to photography. After normalization process, the images are transformed to binary image format to eliminate noise, and then connected component labeling algorithm is implemented on white pixels to filter. After the connected areas of white color are filtered, the remaining blobs are counted to acquire the punctate dotnumber.

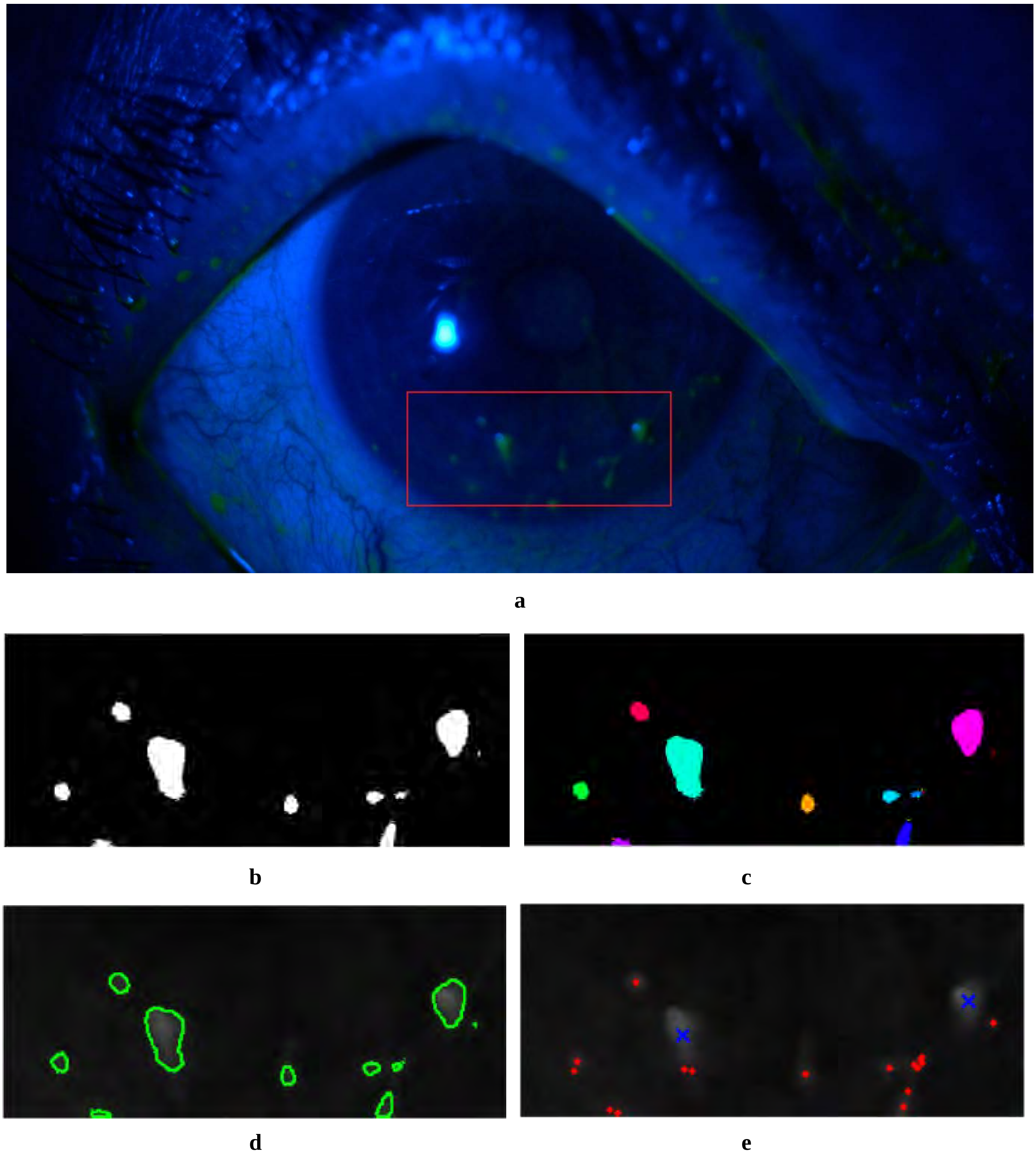


Figure 6: (a) Cropping of the digital image of the inferior cornea based on the ROI (red rectangular region). (b) Binary image after processing the image (extraction of the green channel, image normalization with background smoothing, thresholding) (c) Identifying individual dry areas by seeing which pixels are connected to each other and assigning each distinct dry area a different color (d) Determining the borders of all the dry blobs (e) Counting of punctate dot number (red dots), eliminating of filaments (blue crosses)

In the developed study, user who uses the system firstly defines the ROI by selecting a rectangular region on digital image (Figure 6 (a)). Secondly, images are cropped based on the selected ROI. After initial cropping of ROI parts for each image, the green channel of the images are extracted, so the red and blue channels are discarded, then image normalization with background smoothing is implemented and the image is transformed to binary format. Punctate dots, which show dry areas, are isolated after thresholding process (Figure 6 (b)). A different color is assigned each distinct dry area (Figure 6 (c)). The borders of all the dry blobs are detected (Figure 6 (d)) Detected punctate dot number shows that severity of DES and it is graded based on Oxford grading schema automatically (Figure 6 (e)).

Table 1: Quantative analysis results of each dry blob reported at the end of computational methods

Blob Number	Mean Intensity	Area	Perimeter	Centroid		Diameter
1	34.3	510.0	89.0	86.9	238.1	25.5
2	30.0	3.0	4.0	82.0	253.0	2.0
3	30.1	10.0	14.2	135.6	310.7	3.6
4	31.8	258.0	91.7	147.8	316.7	18.1
5	37.3	623.0	96.9	175.9	118.2	28.2
6	46.9	3954.0	301.3	246.3	198.8	71.0
7	30.0	1.0	0.0	249.0	249.0	1.1
8	30.0	3.0	3.4	258.7	252.7	2.0
9	33.9	434.0	85.0	431.4	257.9	23.5
10	33.0	333.0	82.7	557.4	246.8	20.6
11	35.6	627.0	115.5	578.7	305.5	28.3
12	30.2	6.0	7.4	584.8	283.3	2.8
13	30.7	93.0	45.0	596.0	243.8	10.9
14	30.0	6.0	6.0	599.0	247.5	2.8
15	30.0	6.0	6.0	604.5	237.0	2.8
16	30.0	4.0	4.8	607.5	240.0	2.3
17	31.0	1.0	0.0	608.0	232.0	1.1
18	48.9	2507.0	203.9	676.2	147.3	56.5
19	30.1	19.0	19.9	714.1	180.6	4.9

As seen in Table 1, number, mean intensity, size of the area, perimeter, centroid, diameter information of each dry blob are reported at the end of computational methods to inform ophthalmologists. According to list f the blobs, it can be said that the ophthalmologists can see a detailed quantitative analysis of DES that is not possible in manually conducted clinical evaluation.

4. Results and Conclusion

In this study, an automated grading and diagnosis system for evaluation of DES is implemented to use efficiently in real life; it became possible to access more quantitative analysis than clinical evaluation. The implemented study also avoids the errors that might be caused by specialists' heavy workload; also it helps the specialists in evaluations that require attention. By using this system, the severity of the corneal surface damage can be predicted before an operation. Thus, the specialist can decide if the operation is convenient or not for the related patient. Moreover, treatment procedures can be conducted based on more objective grading results. The data set used in this experimental study continues to grow for future studies. Experiments still continue and are improved as new data is obtained.

Fluorescein staining method is represented by punctate dots that are ordered on a log scale. The logarithmic nature of punctate dot number has been previously observed; that is, the Oxford grading scale follows a logarithmic progression. In Figure 7, the clinical staining score assigned by the ophthalmologist for 40 images is plotted versus the automatically calculated punctate dot number, N_{dots} in logarithmic scale. The number of punctate dots (N_{dots}) is potentially unlimited, however; any images including N_{dots} greater than approximately 1000 have not been seen; that is, log(N_{dots})=3.According to Equation 1, a linear regression calculation of clinical scores versus the automated punctate dot number for each image determined C1 = 1.3244 and C2 = 0.0612. The automated predicted grade is then estimated from this regression fit as follows,

$$G_{pred} = 1.3244 \log(N_{dots}) - 0.0612 \ (for\ N_{dots} > 0) \quad (2)$$

Experimental studies are conducted on a clinical data set of fluorescein-stained eye images labeled based on clinical Oxford grading scale 0 to 4, and when automated score and clinical score are compared it can be indicated that Pearson's correlation between them is 0.981; Lin's Concordance Correlation Coefficients (CCC) is 0.980, 95% confidence interval (0.963–0.989). It is clearly seen that successful automatic DES diagnostic kits can be developed by working on the fluorescein-stained cornea images and implementing computational techniques to assist investigators for a more objective and faster DES diagnosis in real life. Detected punctate dots that can be indicator of DES according to Oxford grading schema are marked in red dots. Detected bigger areas than a predefined threshold value can be indicator of filamentary keratitis disease that is a condition in which strands ("filaments") composed of degenerated epithelial cells and mucus develop on and adhere to the corneal surface causing pain. These areas are not considered as punctate dots and marked in blue crosses.

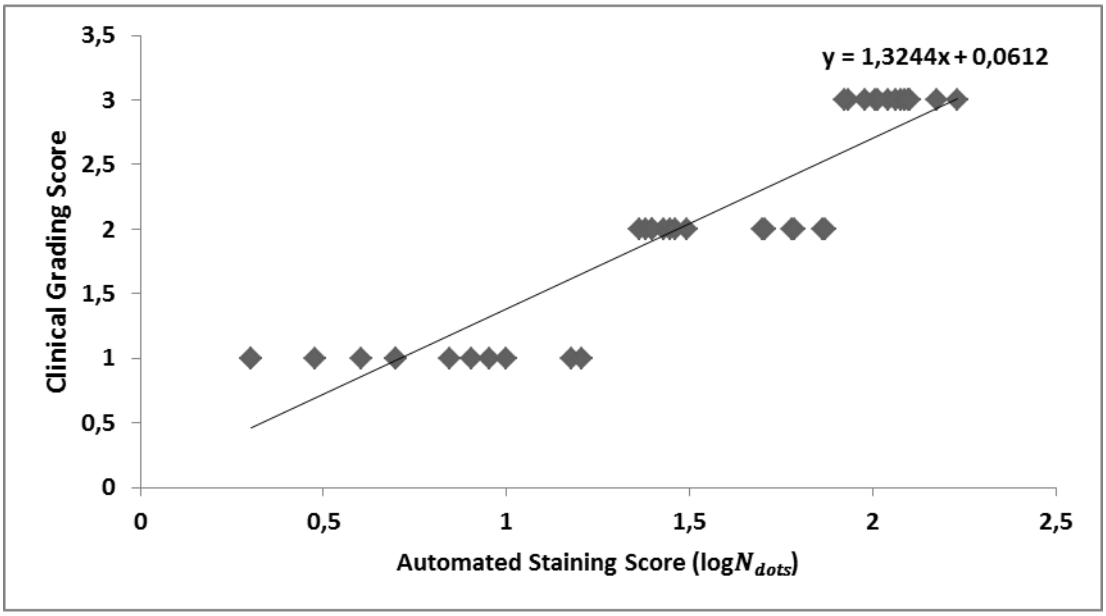


Figure 7: Individual clinical staining scores for all 40 images versus automatically detected punctate dot number (N_{dots}); per linear regression G_{pred} = 1.3244 log (N_{dots}) - 0.0612.

Acknowledgements

We would like to thank to Yıldırım Beyazıt University Ataturk Education and Research Hospital board for their permission to use the digital image data.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Sustainability Effect on Optimum Stock Keeping Unit Variety and Profit

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Abstract

Various consumer needs that force companies to provide different products cause increasing product diversity. It makes product management harder, raises quality and production costs, and increases customer hesitation and dissatisfaction. Therefore companies need to limit product diversity and provide unique products. Additionally, it is critical to find optimal product number for customer satisfaction. Besides, sustainability applications are getting common and companies follow environmental and social parameters in addition to financial parameters. With this study, sustainability issues are included in product assortment problem. Optimum Stock Keeping Unit (SKU) variety and profit is studied for different company and consumer decision with respect to sustainability and economic parameters.

Keywords

Product Assortment, SKU Optimization, Sustainability

1. Introduction

Assortment problem is defined by the determination of product set and inventory level carried in each store at each point in time. The goal of problem is to specify an assortment that maximizes profit or expectation or minimize cost subject to various constraints, such as a limited budget for purchase of products, limited shelf space for displaying products.

Sales and gross margin is highly affected by determination of correct assortment. Retailers' main target is to satisfy consumer needs and increase sales revenue by presenting right products. Besides, the trade-offs with respect to variety, depth, and service levels and providing right merchandise in the right store at the right time is critical. If the retailer fails to provide the expected assortment, consumer might give up buying product. It causes losses in both current and future sales.

Taylar et al. (2009) mentioned that marketing departments launches many similar products with small differences to market in many companies. Stocking, distribution and promotion activities in addition to development and marketing costs raise total costs and induce inefficiencies.

Increase in product diversity let stocking, distribution, development and marketing costs to increase and to decrease consumer dissatisfaction cost. There is an optimum product diversity where companies should focus on. Figure 1 shows the cost and diversity relation and optimum point.

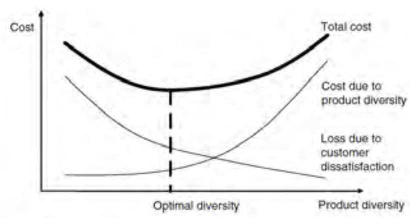

Figure 1. Optimum Diversity and Cost

Product attributes should be included while determining optimum product diversity. Van Herpen and Pieters (2002) studied assortment variety model. They compared assortment variety from an attribute-based perspective and product based approach. In product based approach, consumer compares products one by one. They examined attributes of product in attribute based approach. Product-based approach focuses on the dissimilarity between product pairs in an assortment. The marginal and joint distributions of the attributes is focused in the attribute-based approach that. They conjectured and aimed to show that an attribute-based approach suffices to predict consumers' perceptions of assortment variety.

One of the most commonly used utility based models is Multinomial Logit (MNL) model. It has wide application areas in economics and marketing literatures. Van Ryzin and Mahajan (1999) study the assortment planning problem with a stochastic demand, single period setting with the MNL consumer choice model. Their model allows assortment-based substitution, but does not consider stockout-based substitution. Vulcano et al. (2012) proposed a method for estimating substitute and lost demand when only sales and product availability data are observable, not all products are displayed in all periods (e.g., due to stockout or availability controls), and the seller knows its aggregate market share. The model combines MNL choice model with a nonhomogeneous Poisson model of arrivals over multiple periods.

Despite the objective of most papers in literature is to improve financial performance, awareness, importance and the pressure for the transparency of sustainability have been increasing in the last decade (Artiach, et al., 2010). Business strategies and initiatives are implemented for saving natural resources and satisfying stakeholders' need (Deloitte and Touche, 1992). Economic, social and environment are three pillars of sustainability and the performance parameters of them are widely discussed in literature. Mayyas, et. al. (2012) stated that reduction in natural resources, environmental friendly energy resources, waste reduction and product life cycle assessment are prominent parameters in environmental pillar. Zhoua et. al. (2009) includes sales revenue, purchasing, sales, management, financial, transportation, inventory cost, wages and amortization in economic pillar. They emphasize that products should satisfy society needs.

In this paper, we proposed multi products, multi-level and multi period product substitution problem with transition matrix. We adopt utility based model including sustainability attributes and apply MNL method for matrix calculations. As Sarigol and Ozkan (2016) stated, sustainability effects of assortments are not considered in the literature and sustainability against profit and SKU variation needs more attention to make research. Hence, we evaluate various scenarios by solving the proposed mixed-integer programming problem to optimality. We use reel life data from a tyre company and deduce some problem specific results.

This paper is organized as follows. Section 1 provides a brief motivation, background and describes previous works closely related to the current research. Section 2 describes the model and solution methodology. Section 3 presents the results and Section 4 provides discussion and concludes the paper.

2. Model Development and Solution

Sales and cost data is collected with respect to product attributes. Later, mathematical model is generated by using data files. Again using data, Transition Matrix is calculated with MNL Regression in SPSS. Discrete time Markovian Chain is studied in this paper. All data files and Transition Matrix are input for the mathematical model coded in GAMs.

Dhar (1997) mentions that the attractiveness of SKU is related with its attributes. While developing correct SKUs, it is critical to determine attributes that present consumers' preference correctly. Information Resource Inc. (1989) defines the criteria such as; an attribute should be identified from the package and should not create doubt for consumer. Additionally, attributes should be easily separated by each other.

The product is tyre with 7 well defined attributes in this study. Each of them is clearly understood form the tyre. Brand can be seen on product easily. Wet grip, fuel efficiency and noise level have to be defined on product legally. Speed rating and weight can be seen on tyre. Selected attributes are mutually exclusive and level of each attributes defined objectively. Product attributes are classified into two groups which are economic and sustainability. In tyre sector, while weight and fuel efficiency (rolling resistance) are considered as environmental attributes, wet grip, noise are social attributes. Increase in product weight raise material consumption and the existence probability of hazardous materials and waste. Fuel consumption which is the function of rolling resistance is directly related with emission rates. Wet grip is one of the main factors in traffic accidents and injuries. Noise level affects the quietness and quality of city life. Remaining parameters are classified in economic group.

Multi product, multi dimension decision problem is studied in the model. Objective function comprised sustainability and economic part. Sustainability is calculated by multiplication of sustainability value and product sold. Economic part is the difference between revenue and loss which is the summation of linear inventory, quality, production and substitution cost functions. Substitution is calculated by subtracting cost of switching products.

If a product is started production in a term, the depreciation cost incurs for oncoming terms. Purchasing cost is applied for imported products. Inbound and outbound logistic costs are not included in model. Besides, it is assumed that manufactured and imported products are distributed to consumers with same distribution channel in same conditions.

It assumed that demand decreases with a constant as the number of offered products increases and demand is deterministic and known. Sales data of each product represents the demand of them. It is a Static demand model. If the product that consumer wanted to purchase does not exist on shelf, it assumed that consumer will either buy an alternative product instead or give up buying the product and lives the store. There is a probability that consumer will buy an alternative product. A transition matrix, shows the probability of passing from one product to others, is calculated from sales data by using MNL distribution. Each year transition matrix is calculated because some of products are discontinued and some new products are launched. Besides, changes in consumer preferences cause transition matrix to be calculated for more accurate decision.

Three different transition matrixes are calculated by considering product attributes. Only economic, only sustainability and both of the attributes are used. Similarly company selects one of the objective functions alternatives which depend on only economic, only sustainability and both of them.

Sarigol and Ozkan (2016) give the details of the model and solution in "Sustainable Stock Keeping Unit Optimization" paper.

3. Empirical Analysis

We studied nine scenarios in the paper. Company and consumer have three different alternatives. When consumer give decision depending on sustainability attributes, company could reacts with 3 different alternatives. In total, there are nine different scenarios. Table.1 summarizes the aggregate results. Maximum profit and objective value is obtained with 8 SKUs. Maximum sustainability value is achieved at solution with 9 SKUs.

Table 1. Aggregate Results

SKU	Object	Profit	Sustain	ave_price	ave_sust
1	9.561.058	9.630.163	6.285.466	165,8	55,5
2	16.296.948	16.720.674	11.563.090	166,2	54,4
3	18.586.968	20.228.003	14.540.507	166,8	51,9
4	20.432.352	22.024.493	16.292.824	167,1	52,7
5	21.023.594	22.684.791	17.348.758	166,9	52,6
6	22.068.326	24.232.676	18.064.940	168,1	52,9
7	21.553.559	23.885.921	17.167.380	168,8	52,8
8	22.394.733	24.584.231	18.591.867	168,6	53,6
9	22.330.903	24.398.324	19.303.389	168,1	53,0
10	21.866.278	23.215.768	18.889.968	167,9	53,1
11	21.833.313	23.313.201	18.293.518	168,4	53,0
12	21.933.866	23.469.277	19.045.769	168,2	52,7
13	21.390.464	22.647.423	18.841.382	168,2	52,8
14	21.599.246	22.960.276	18.985.942	168,7	52,8
15	21.056.419	22.233.159	17.441.243	170,4	53,2
16	20.506.678	21.444.693	17.825.182	169,8	53,2

Objective function values increase while product variety increases at a certain point. Later it starts decreasing. Ave_price increases and ave_sust value decreases with increasing product variety. Figure 2 and Figure 3 shows the aggregate results of the scenarios respectively.

Ave_sust shows the average sustainability value of products sold. In case ave_sust value increases, more sustainable products are presented to market.

When company gives decision with respect to economic parameters, ave_sust value raises with increasing product diversity independent form the consumer preference. The highest increase occurs when consumer preference depending on economic parameters with greatest slope in linear regressions. Increase in product diversity let company to market more sustainable products.

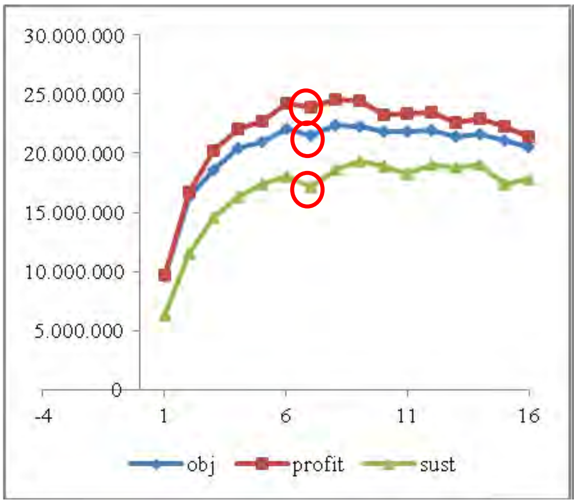

Figure 2

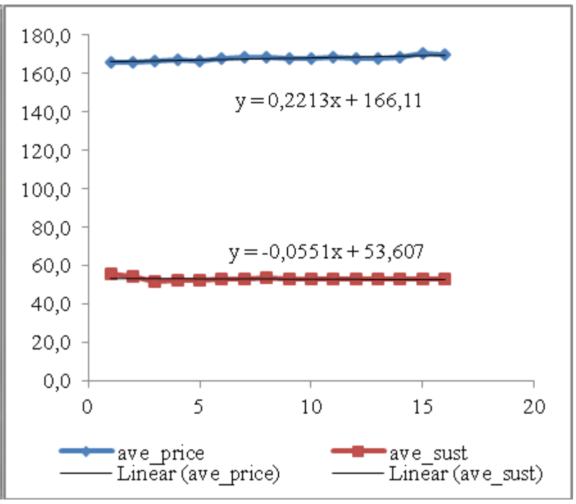

Figure 3

When company gives decision depending on sustainability and economic parameters and consumer preference with respect to economic attributes, there is small increase. In the remaining scenarios it has a decreasing tendency. Ave_sust value decreases with increasing product diversity.

Ave_sust value either increases or decreases with respect to consumer preferences, when company considers only sustainability parameters.

In summary, company or consumer give decision depending on only sustainability parameters, ave_sust value that starts from lower value raises with increasing product diversity. In Figure 4, increase in product diversity cause decrease in ave_sust value that starts from higher value in cases shown in red frame.

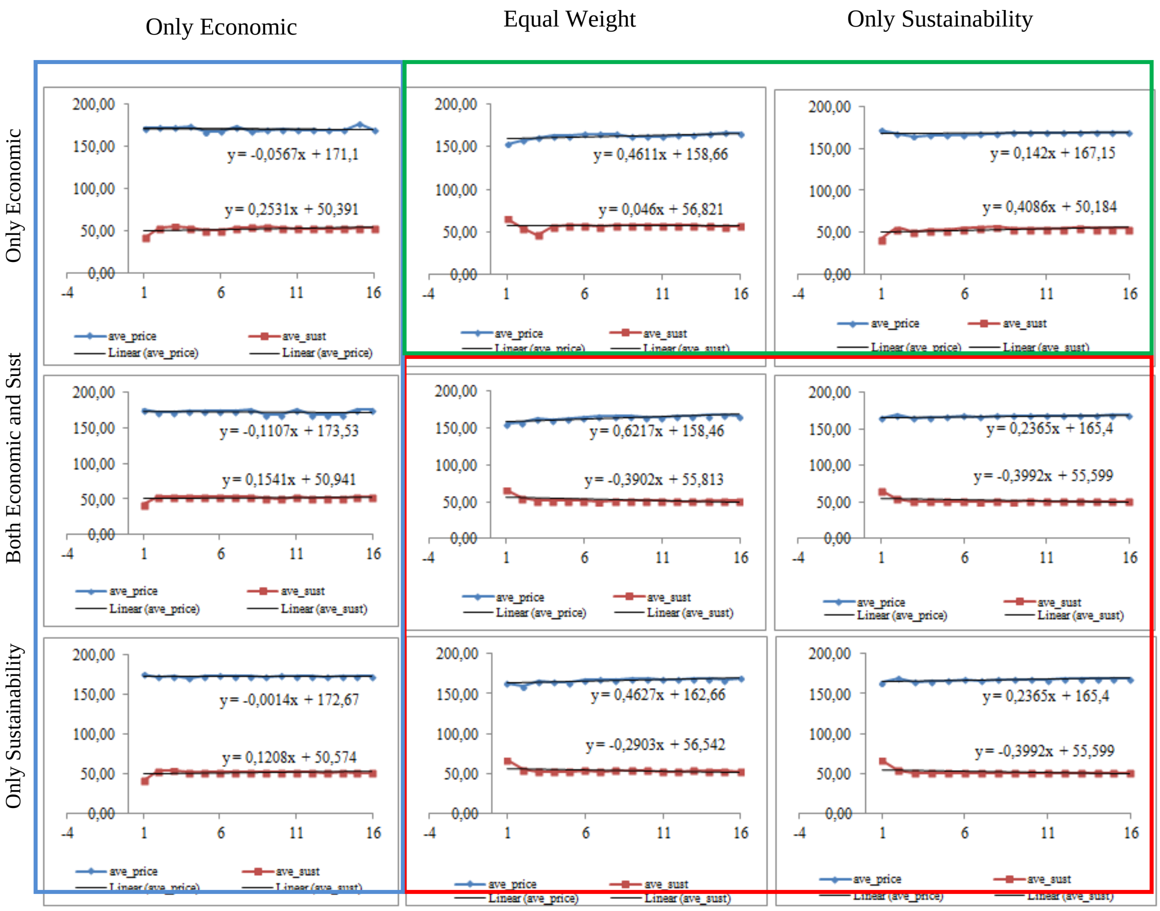

Figure 4

Increasing product diversity causes decrease in ave_price when company gives decision depending on economic parameters independent from consumer preferences. It is shown with blue frame in Figure 4. It is because company prefers highest profit products at first.

When we compare ave_price and ave_sust values, we observe a negative relation in scenarios shown in Figure 4 except scenarios in green frame.

Sarigol and Ozkan (2016) analyzed solutions according to customer and company decisions in detail. They highlighted that maximum profit is obtained at when consumers give decision depending on sustainability attributes and company considers economic parameters.

The highest sustainability gain and average sustainability value is obtained when consumer preference depending on economic attributes and company abides by sustainability parameters.

In case consumer pass between products according to sustainability attributes and company does not consider profit and decide depending on sustainability parameters, products with low price and high sustainability value are put on market. On contrary, when consumers consider sustainability attributes and company determines economic parameters, product with higher price with low sustainability value is presented.

Table 2. Consumer and Company Decisions

		Company		
		Economic	Equal Weighted	Sustainability
Consumer Preference	Economic	SKU: 8 Profit: 25,6 M TL Sust: 19,7 M unit Ave_price: 168 Ave_Sust: 54	SKU: 8 Profit: 25 M TL Sust: 20,8 M unit Ave_price: 168 Ave_Sust: 57	SKU: 9 Profit: 19,9 M TL **Sust: 21 M unit** Ave_price: 162 **Ave_Sust: 58**
	Econ and Sust.	SKU: 9 Profit: 24,8 M TL Sust: 18,5 M unit Ave_price: 169 Ave_Sust: 51	**SKU: 6** Profit: 25,1 M TL Sust: 18,5 M unit Ave_price: 168 Ave_Sust: 51	SKU: 8 Profit: 23,7 M TL Sust: 18,9 M unit Ave_price: 166 Ave_Sust: 52
	Sustainability	SKU: 7 **Profit: 28 M TL** Sust: 18,8 M unit **Ave_price: 173** Ave_Sust: 52	SKU: 9 Profit: 24,7 M TL Sust: 18,4 M unit Ave_price: 168 Ave_Sust: 51	SKU: 9 Profit: 25,7 M TL Sust: 19,7 M unit Ave_price: 169 Ave_Sust: 54

Similar profit and sustainability values are obtained if consumer and company consider both sustainability and economic parameters together. Table 2 presented by Sarigol and Ozkan (2016) summarizes consumer and company decisions and results. Highest sustainability and profitability is obtained when consumer and company decisions are opposite. It is because of the relation between product sustainability value and unit profit.

It is widely stated that sustainable products are more expensive than the non-sustainable variants. When we analyze unit profit and sustainability value of product in our data, we realized that there exists different pattern. Products given with blue circle in series 1 distorts the relation between unit profit and sustainability value. We call these products as “frontiers”. If we remove these products from the list, series 2 is obtained. We observe a negative relation between sustainability and profitability as stated in the literature if we remove frontiers from the product list.

Besides, we divide remaining products into two groups which are “secondary” and “discontinued”. Secondary products are more profitable and sustainable compared to discontinued ones. Secondary products are above the regression line. Red and green circles show secondary and discontinued products respectively. When company increases sales of secondary products, profitability and sustainability will also increase. On the other hand, company should eliminate discontinued product by considering consumer needs. If these products are preferred by specific consumer group, alternative products should be presented considering sustainability and profitability.

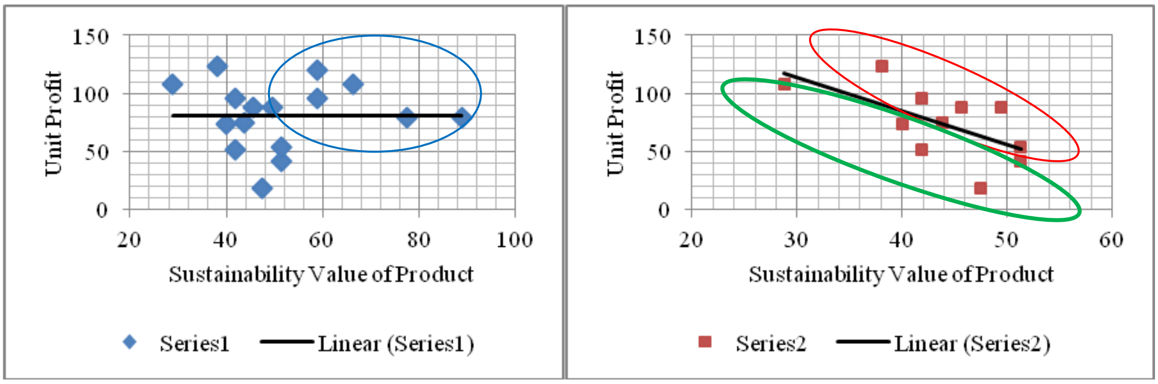

Figure 5. Sustainability Value and Unit Profit Comparison of Products

4. Results and Discussion

Sustainability affect on stock keeping unit is studied in this paper. Optimum variety of SKU calculated in scenarios is less than number of product put on market. Analyses on ave_sust and ave_profit are presented. Unit profit and sustainability value behavior is also investigated.

It is observed that there exists a negative relationship between ave_price and ave_sust values. Decreasing ave_price generally increases ave_sust value. However, this relationship is problem specific and should be considered with respect to original problem. When company gives decision depending on economic parameters, ave_sust value raises with increasing product diversity. When company gives decision depending on sustainability and economic parameters, ave_sust value decreases with increasing product diversity. Besides, company or consumer give decision depending on only sustainability parameters, ave_sust value that starts from lower value raises with increasing product diversity.

Company obtains the highest sustainability value when consumer make preference depending on sustainability attributes. On contrary, when consumers prefer more sustainable products and company acts regarding economic parameters, the highest economic gain is obtained.

In the literature, it is widely believed that sustainable products are more expensive. In our case, frontier products change this relation. When these products are not included in the product list, more sustainable products generate less profit. Hence, companies should examine products and determine which products to keep producing. This classification helps companies to manage product portfolio.

To the best of our knowledge, despite the attribute based consumer driven studies and assortment problem is widely studied in the literature, sustainability attributes is not common. Both consumers and company can give decision depending on sustainability issues. Their conditional actions present information to make comparison between different scenarios.

It is worth to study deeper the product classification and further to compare three class of products. Besides, product attributes are only considered in sustainability calculations. Different parameters in product life cycle can be included in analyses.

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Biography

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Supply Diagnostic Incentives in New Product Launch

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Keywords: Supply risk; New product development; Information asymmetry

Topics: Supply Chain Management; Operations Risk Management and Resilience; Innovation, Product and Service Development

Research Problem: In this paper, we analyze the value of diagnostic test when supply chain parties are both uninformed about the supply-side risks due to lack of experience in new product manufacturing. This lack of information leads to not only supply side problems, such as yield problems, and lack of flexibility in production capacity but also demand side problems, such as lost sales, customer goodwill loss, and market share loss due to a fast follower [1]. For example, the IBM's $150 million first-quarter loss in 2004 is attributed mostly to the yield problems that are realized when the company introduced an untested process technology to manufacture a new semiconductor-based product at its microelectronics plant in East Fishkill, New York [2]. Therefore, in order to reduce the likelihood of failure of a new product development project, the buyers may want their suppliers to invest in a costly diagnostic test technology, e.g., running a test production, before commencing the final production. This paper aims to analyze costs, and benefits of such supply diagnostic test in a new product development project.

Model Framework and Research Methodology: To achieve the main research objectives, we develop a dyadic supply chain model where a buyer outsources the production of a new product to a supplier who faces a supply risk. Furthermore, due to lack of experience in production, the extent of risk is ex-ante unknown by both the buyer and supplier. In order to reduce the extent of risk, the supplier has to decide whether to improve his process at a cost before starting the actual production. We consider two variants of this model on the basis of whether the diagnostic test is available to the supplier or not. Under the first case where the diagnostic test is not available, the supplier makes his process improvement decision without taking any diagnostic decision. On the other hand, in the second case, the supplier can invest in a costly diagnostic test (such as running a test production) to learn the true state of his reliability, and make optimal process improvement accordingly. By using mechanism design theory [3], we analytically characterize and compare the equilibrium contracts and decisions for the above two models to answer our research questions.

Results and Contribution: The results in this paper shed some light on the use of diagnostic tests for new product development [4]. Specifically, the advantages and disadvantages of diagnostic tests should be carefully weighed by the firms in aerospace, defense and high tech industries (such as IAI, Apple, and IBM) where the diagnostic procedures are very costly, and the degree of information asymmetry that results from obtaining private information is highly crucial. If the incentives between the supply chain parties in these industries are not aligned properly, the information asymmetry amplified due to presence of diagnostic test could indeed neutralize all the benefits of diagnostic test, leading to the worst-case outcome for all the parties.

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Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Customer Profiling for Co-creation in Global New Product Development

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Abstract

The importance of customer co-creation in customer centric new product development (NPD) has been discussed in the literature, comprehensively. However, according to our best knowledge, there is still a need to discuss and highlight the issues and trending approaches faced/required while addressing customer co-creation in decentralized and multi-site international companies. Furthermore, we also think that the origin of these discussions should be shifted to computer-aided innovation (CAI) domain because this kind of interactions is a matter of virtual co-creation, i.e. it is highly depended on sophisticated and specialized information and communication technologies (ICTs). Correspondingly, this study investigates “customer profiles” for co-creation in global NPD. Customer types and their possible contributions for virtual co-creation are discussed in this study by considering each phase of the new product development process.

Keywords

Customer Co-creation, Global New Product Development, Computer-Aided Innovation

1. Introduction

Meeting customer needs, desires and wishes is becoming more and more decisive and challenging in the environments, where organizations and producers compete. And it is not a secret that satisfying customer needs highly influential on viability of organizations in competitive market force. Therefore, searching for appropriate ways of customer participation in new product development processes has been an active research area.

It is also clearly reasonable that enabling customers to play active roles in this collaboration process is an essential prerequisite to realize customer participation better. Responding customer demands, which can be provided with interaction between organization and customer, has become vital to protect position of organizations, and to gain and sustain competition.

Empowerment of customers in the experiencing environment in their terms creates value that can be generated with removing firm-centric view in the organization and getting closer to customer-centric view. Creation of value in this interaction is manifested with jointly participation of parties, that picture is about co-creation (Prahalad and Ramaswamy, 2004). Involvement of customers in the customer-centric view helps clearly understanding customer needs, and meeting these needs is ended up better new product developments that decrease rates of failure (Hauser et al., 2006). Therefore, customer co-creation in new product development is becoming prominent for organizations.

In the literature, there are several customer integration methods and basic target of these methods is to gather knowledge from customers and put them into the development process (Zogaj and Bretschneider, 2012). However, the challenging task is to determine which customer type is going to be integrated into which stages of the new product development process.

On the other hand, in global and/or dispersed new product development projects, which are more difficult to succeed with traditional methods, requires new ways to uncovering uncertainties regarding customer needs. According to complexities and difficulties in the competitive environment related with global new product development project, customer co-creation in the “virtual environment” has become more attractive in global new product development so as to putting different customers with capabilities, personalities, sources and knowledge together, effectively and efficiently.

We have encountered some customer types which can be categorized into different segments and profiles by reviewing academic literature. In this study, we present our initial findings about customer profiles for co-creation in new product development.

2. Customer Profiling

Innovation can be triggered by “users” if it is assumed that experience is instantly occurred in terms of usage pattern of products. When user has been analyzed in general terms, it is seen that user can be functioned as both “customer” and “consumer” in terms of their roles in new product development (Per Kristensson et al., 2008). Investigation of “users” under the roof of “customer” and “consumer” may be meaningful with regard to their activity in new product development due to the inheritance features and directions of them covered by both customer and consumer. That may be more helpful to achieve distinction of customer from users (and consumers) to integrate customers into the new product development process and to prevent confusion between all of them. It should also be noted that, in this study, customers are not only considered as individuals but also as institutions or corporations.

In the literature, the terms “user”, “consumer” and “customer” are used, interchangeably (Dereli and Altun, 2012; Kaulio, 1998). According to technological development, increased competition and emergence of unmet needs in the market, traditional marketing view and efforts has changed and usage form of those terms has started to become evident. Users who primarily take into account satisfying their needs benefit from using a product (von Hippel, 1988). They can also cover their unfilled needs with innovation by themselves (von Hippel, 2005). “User” can be a firm, that is also called as an “intermediate user” (Bogers et al., 2010), or an individual who buy, use and consume a product, although “consumer” can be defined as a person who consume a product (Blythe, 2005; Dereli and Altun, 2012). It can be said that “consumers” accept existing products whatever they find even it doesn't satisfy their needs. Because, “consumers” were obliged to express products by organizations in traditional marketing view and that was not essentially enough to fulfill customer requirements. They only concentrated on how to buy products and how to consume it. This process had been also managed by corporations where exchange of value was appeared at buyers of products (passive customer).

Difference between “customers” and “consumers” is related with their social interaction with provider and their evaluation of value through making trade-offs (Dereli and Altun, 2012). This process may be referred as “co-creation” in new product development where active participation of customers are come true (Hoyer et al., 2010). With the help of developments in information and communication technologies (ICTs), re-evolution of consumers into customers, that is also a new way of source of competence, has been started to become. Therefore, disposition of consumers from value exchange to creation and competition of value in dynamic market place has been started to come true (Prahalad and Ramaswamy, 2000). Customers are no longer consumer of value and passive audience of value chain. They are active participants and collaborators for organizations where customer co-creation is suitable form to source of sustaining competitiveness of companies and satisfaction of customer requirements.

To keeping up competitive position of organizations in the market, comprehension of customers and satisfaction of them is important. It has started to get a bit tricky nowadays because the rate of change in competition and customer requirements are evolving faster. Meeting their needs with innovation is necessary and it can be possible with developing new products (Hauser et al., 2006). To succeed in new product development projects, that depends accurately understanding and satisfying customer needs, is achieved by empowerment of customer in new product development process (Hoyer et al., 2010; Prahalad and Ramaswamy, 2004). Therefore, shifting from passive audience to active player is taken place by consumers. However, customer are called and used in different ways, such as consumer and user, in new product development literature. Sometimes, it is expressed with the usage of consumer or user (Per Kristensson et al., 2008). Interchangeable usage of these terms may not be suitable. The separation of expression between these terms and of tasks they undertake may be necessary for the success of new product development projects. A categorization of the customer profiles is given in Table-1.

Ordinary users/customers have lack of technological knowledge related products and services. It may lead to hesitate socially and psychologically and to fear which can negatively effects their motivations (Weber, 2011). Low level of motivation might decrease willingness of participation of customer in the innovation process, and that can decline level of use experience. However, according to not encompass with prevailing dominant logic as experts, they may also generate valuable and creative ideas (Magnusson, 2009).

Table 1. A categorization of the customer profiles

Customer profile	**Personnel traits**	**Customer role**
Innovator ´ Technically ´ Technologically	 ´ Technical knowledge, Experience ´ Technological knowledge, Creativity	 ´ Entrepreneurial ´ Competitor
Lead User ´ Trend-aware ´ Opinion leadership	Competency, Motivation	Collaborator, Co-developer, Co-producer
Ordinary users	Ideation customer for value	Resource provider
Requesting customer	Provider of idea for NPD	Information provider
Launching customer	Development of design activities	Co- developer, Co-creator
Emergent customer		
Pioneering users		
Professionals	Innovator	
Experts	Innovator	

In contrast to “ordinary users”, “lead users” have better use experience and technological knowledge. They encounter needs months or years before bulk of the marketplace face them and they also benefit finding solutions for those needs (von Hippel 1986, 1988). According to some empirical studies, highly innovative and commercially attractive products can be provided with regard to lead users (Herstatt and von Hippel, 1992; Lilien et al., 2002).

According to Lettl et al. (2006), “lead users” have also some characteristics such as openness of new technologies, interdisciplinary know-how and intrinsic motivation. They have also trend leadership depending upon need and solution experience that might make possible for creating commercially attractive products.

Moreover, being ahead of the market trend of lead users may be possible experiencing tomorrow’s needs today that can be helpful to create better new ideas for tomorrow products (Lüthje, 2004). Besides, diffusion of innovations based on social interaction and information providing can be carried out by lead users owing to opinion leadership characteristic of lead user (Bilgram et al., 2008; Morrison et al., 2000). While experiencing needs to fill and solving problems, new product ideas can be originated and new product concepts and designs can be provided.

“Experts” / “advanced users” have some characteristic similarities when compared with “lead users”, but they realize mistakes of prototypes while testing developer's product (Arvanitis et al., 2011; Jeppesen 2005). Use experience and product-related knowledge are components of user expertise (Bilgram et al., 2008). Their frequent usage pattern of prototypes and testing products may provide realizing benefits and shortcomings faster than not only “lead user” but also others. Moreover, development of new product concepts and designs produced by “lead user” can be tested by “experts” whether they are feasible and/or reasonable. Manifestation of feedback from advanced/expert user to lead user might help detecting latent needs which will be general in the future. Expert users, who stay under pressure of problems, constrict them to find new solutions (Lettl et al., 2006). Therefore, enhancing their expertise and skills for a specific area might be better than “lead user” because of dealing with long term for that subject, and they can find more creative and novel solution.

Enkel et al. (2005) present different customer types and their contribution and effects to new product development processes. It is argued that customers with different skills and knowledge create different solution depending on which phases they are integrated. “Requesting customers” provide suggestions and complaints as an idea (Enkel et al., 2005). Requesting customers’ contribution, which is also related with organizations knowledge capture capabilities, may takes shape with their motivation and willingness of providing ideas and selection of suitable customers by organizations (Enkel et al., 2005). This is also missing feature of ordinary user at their own side where engagement of customer will be difficult (Weber, 2011).

“Launching customer” is another customer type who is integrated beginning of the development activities such as concept development phase to design, test and development activities. As in the example of (Herstatt and von Hippel, 1992) lead user empirical study, choosing 22 lead users inside the 74 individual according to their features for development activities may be presented as launching customers. However, some of them may not accept presenting their product ideas. The remaining customers, who have willingness to participate, can be referred as “reference customers” because of sharing their experience.

3. Concluding Remarks

In the era of rapidly increasing of competition, understanding customer needs and requirements becomes crucial for organizations and success of developed new products. Since the existence of customers with different propensities, some innovation strategies, e.g. “continuous & discontinuous innovations” (Veryzer Jr., 1998), “sustainable & disruptive innovations” (Christensen, 1997), “incremental & radical innovations”, have been deployed to cover their preferences. However, type of the innovation made and their effects over individuals may differ with respect to customers and their daily customs. Maintaining previously preferred operations (traditional firm-centric view) doesn’t meet customer requirements in today's competitive environment. Informed, networked, empowered and active customers are no longer accept dominantly imposed products (i.e., technology push) and they prefer collaboration with company and experiencing on by their own (i.e., demand pull). With regard to this situation, moving towards from mass production and mass customization to co-creation is necessary for jointly creation of value and sustaining viability of company. Consequently, Participation of customers into the new product development as an active player and collaboratively creation of value with company (customer co-creation) will be realized which can be helpful to satisfy customer needs and product success.

During participation of customers into the new product development processes with different personal traits and roles, choosing right customers for the right phases is important to encompass their knowledge and experience. However, articulation of customer experience and knowledge is hard and complex because of their tacit nature, and that is getting harder and harder in global new product development projects. To overcome this difficulty, use of advanced ICTs (e.g., automated and multi-issue negotiation mechanisms) should be preferred to solve encountered complexities and dynamic customer requirements (Altun et al., 2016). This kind of ICTs needs to take customer profiles into account as well. Therefore, we will extend our study in future work by reviewing customer profiles in detail.

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A New Mathematical Model Towards the Integration of Cell Formation and Part Scheduling

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Cellular manufacturing system is an implementation of group technology. The similarities of parts and available machines are considered to form possible manufacturing cell designs in order to process parts on dedicated machines [1]. Cell formation, cellular layout, and part scheduling in cells are three major decisions to design cellular manufacturing systems. Although most attention paid to cell formation decisions, relatively few works considered two or more together [2,3]. In literature, integrated studies are not examined as rigorously often as individuals. In this aspect, cell formation and parts scheduling in cells are two important decisions in the multistage processes of cellular manufacturing systems. In this paper, a new mathematical model has been developed to solve cell formation and job scheduling problems, simultaneously. The objectives of the model are minimizing the total exceptional elements and the makespan of the jobs in cellular manufacturing environment. After introducing the proposed mixed integer linear programming model, the validity and the practicability of the model have been illustrated on numerical examples. The results show that considering cell formation and part scheduling in cells decisions simultaneously can significantly improve the performance of the cellular manufacturing systems.

Acknowledgements
This study was supported by the Eskisehir Osmangazi University Scientific Research Projects Committee under project number 2015-787.

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Literature Review on Modelling, Analysis and Planning of Emergency Evacuation Process For Public Marine Transportation

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Abstract

More crowded groups of people gathers in passenger ships as a result of increasing demand and variety of navigation. Each company/institution performing public marine transportation activities should consider the security of passengers and crew. In this context, providing effective evacuation of passengers from ships becomes an important concept with respect to passenger safety. Evacuation of people can be defined as directing or taking away many people from an area under the existing or potential hazard to a relatively safe place in a planned manner. Supporting evacuation via effective planning has a vital importance for passengers and crew. The evacuation process on a ship can be very different from evacuation on building due to lack information of passengers about ship layout, complex geometry of the passenger ship and the special environmental factors limiting the movement ability of passengers such as trim and heel. The potential of public marine transportation and the effect of evacuation on life safety inspire the proposal of this study. However, there is a lack of sufficient literature review studies that investigate emergency evacuation. This paper offers a review of the literature on maritime emergency evacuation during the period from 1940 to 2016. The objectives of the review are to: identify and explore patterns and trends in publication outlets; collect, document, scrutinise and critically analyse the current literature on this field; to identify gaps in the literature; and make recommendations for further research in this field. To accomplish this task, the data from specialist academic journals, conference papers and technical reports of agencies are collected, reviewed and summarized based on a systematic review approach. Distributions of studies with respect to method, publication year, document type and country are proposed.

Keywords

Evacuation, maritime, marine accidents, transportation, simulation, systematic review

1. Introduction

Emergency evacuation is the immediate and urgent movement of people away from the threat or actual occurrence of a hazard. Examples range from the small scale evacuation of a building due to a storm or fire to the large scale evacuation of a district because of a flood, bombardment or approaching weather system. As a result of marine accidents all over the world between 2002 and 2009, 6899 loss of life has occurred and 1082 ships became sunk or unavailable (IMO, 2010). Many lives are lost around the world due to passenger ships accidents. After the great loss of life from the accidents of the Estonia and the Herald of Free Enterprise in Northern Europe, the Maritime Safety Committee (MSC) of the International Maritime Organization (IMO) made evacuation analysis of Ro-Ro passenger ships during the early design stage mandatory (IMO MSC/Circ. 909), in order to save as many lives as possible. The current requirements for the evacuation analysis by the IMO is to fix the value of the main factors such as the effective width of exits and the movement time of persons, and calculate together with some restrictions. This is effective to prepare necessary equipment and specifications such as the width of the corridor and the slope of the steps. However this is not enough for increasing the degree of passenger safety to a satisfactory level. Consequently, IMO has only imposed this regulation temporarily until the necessary technology for the analysis of the evacuation simulation is developed (Lee, Park, & Kim, 2004).

In 1995, the St. Malo, a high-speed catamaran passenger ship with length of 41 m, was damaged, and passengers were evacuated as the ship was listing and in motion. The sea conditions were favorable, it was daylight, and most passengers were in the saloon. However, although the evacuation situation was comparatively good, the evacuation time for 308 passengers was recorded as 1 h and 17 min (Lockey, Purcell-Jones, Davies, & Clifford, 1997). The evacuation time recorded during the drill in static conditions was 8 min. This shows that evacuation analysis is meaningless in practical situations if it does not take account of rolling, pitching and listing of the ship, and panic of the passengers (Kim, Park, Lee, & Yang, 2004).

For the simulation of an evacuation analysis, technology should take account of (1) the geometric model for the evacuation analysis, (2) the evacuation analysis algorithm, (3) the behavior of people under such conditions, and (4) the effects of pitching, rolling, and listing. The geometric model is mainly composed of compartments, such as passenger cabin, corridors, stairs, and the mustering area. The evacuation algorithm, which is mostly derived from traffic control or particle movement studies, is used in the places such as airplanes, buildings and concert halls, where a lot of people are concentrated in one place. Analysis of human behavior in emergency situations deals with human factors that are hard to analyze by experiments. These factors include cultural differences, gender, age, behavior under panic, and so on. The effects of pitching and rolling, which are not significant in ground buildings, are considered as the dominant factors in ships; they have direct effects on the behavior of people, and are especially critical for senior people and those with physical disabilities.

The research goal of this paper is the systematic search of the related studies in emergency evacuation sources, the filtering of those who are most relevant to the aforementioned research subject, the classification of them based on specific characteristics, and finally, the aggregation of the results that are presented in the studies in order to understand better the consequences of this kind of events, extract general conclusions and utilize this aggregated knowledge for future research. The rest of the paper is organized as follows. ...

2. Related works

Literature reviews constitute a very powerful tool in the hands of the researchers, since they aggregate in summarized form all the information about the research in a specific field. Hence, many literature reviews have been conducted during the last decades in many different scientific areas: medicine, physical sciences, social sciences, economics and others. Especially in computer science, literature reviews are very common, mainly due to the new fields that continuously emerge with the evolution of technology. The most related works with the current systematic literature review are reviews regarding the stock market reaction to events related to information technology. These papers are studies analyzing either the impact of IT investments (management information systems, e-commerce, ERP, CRM, DSS) to the stock price of firms, or the impact of general IT events (including IT investments, Information Security, IT outsourcing and others) on the market value of firms.

A review of the methodologies used in the computer simulation of evacuation from the built environment was conducted by S. Gwynne, et al., (1999). They used the traditional literature review approach and mentioned that “computer based analysis of evacuation can be performed using one of three different approaches, namely optimization, simulation or risk assessment. Furthermore, within each approach different means of representing the enclosure, the population, and the behavior of the population are possible” (Gwynne, Galea, Owen, Lawrence, & Filippidis, 1999). In their paper, the myriad of approaches which were available has led to the development of some 22 different evacuation models and attempted to describe each of the modelling approaches adopted and critically reviewed the inherent capabilities of each approach.

Lee D. et al. (2003), in their work with the name of “The current status and future issues in human evacuation from ships”, reviewed the requirements of the IMO and the researches regarding ship evacuation. They concluded that the current IMO regulations do not effectively reflect complex factors such as a ship’s list and motion, physical restriction and the psychological factors that are very important in the real world. The IMO realized these limitations and, at the MSC meeting held in May, 2001, it reviewed microscopic methods (IMO, 2001). The most important aspect in microscopic methods is acquiring sufficient and accurate data of the behavior of each individual.

3. Methodology

The systematic literature review that is presented here follows the procedures that are described in Kitchenham (2004) and Kitchenham and Charters (2007). Although these guidelines are software engineering-oriented, the basic principles are essential, generic and valid for any literature review so they were also adopted for our systematic review. According to the aforementioned guidelines, this systematic literature review has three stages: the *Planning Stage*, the *Conducting Stage* and the *Reporting Stage*. The first step of the planning stage referred to the *identification* of the need for a Systematic Review (Spanos & Angelis, 2016). As described in the previous two sections, there is no any compulsory review in the field of emergency evacuation that summarizes studies and offers a deeper insight to this crucial research area. Therefore, the need for a systematic literature review that will provide the researchers with information about the methodology used and the results found so far is obvious and essential.

The second step of the Planning Stage is the *development* of the Review Protocol. Essentially, the Review Protocol defines the whole procedure of the Conducting Stage by analyzing the necessary actions that have to be accomplished in order to continue with the Conducting Stage. These actions are described next and they are: the definition of research questions, the selection of the search strategy, the definition of the study's inclusion/exclusion criteria, the definition of the study quality assessment criteria and finally the selection of the data that will be extracted from the studies.

The review protocol is refined during the entire procedure of the systematic review. The *definition of research question(s)* is a very crucial step in every systematic review. By answering these questions, literature reviews essentially accomplish their aim. The research questions of the present systematic literature review are stated below:

• How many research studies exist, having as subject the marine accidents and maritme emergency evacuation?

• What types of emergency evacuation events have been analyzed in the literature?

• What types of studies have been conducted in the existing literature?

• What are the results of the studies and the significance of them?

The first step of deciding the *search strategy* involves the selection of the search method that can be one of the following: the *broad automated search* in digital libraries, the *manual search* in specific journals and conference proceedings, the *snowball technique* (backward or forward) or a combination of the previous methods. In the present systematic review, we decided to use a combination of the broad automated search and the backward snowball technique. The broad automated search method includes the selection of the most appropriate digital sources (digital libraries and indexing systems) and the determination of the search terms. The sources that were selected in the presented literature review are the digital libraries of: Science Direct (http://www.sciencedirect.com), CiteSeerX (http://citeseerx.ist.psu.edu), IEEE (http://ieeexplore.ieee.org), Web of Science (https://webofknowledge.com) and Scopus (www.scopus.com).

The backward snowball technique was used as a complement to the broad automated search in order to find papers that cannot be found by the first method. The backward snowball technique is essentially the iterative review of the references of an initial set of papers. At each iteration, this set is updated by finding new related papers while the procedure ends when no more new papers can be found. The combination of the two techniques increases the probability that the systematic literature review covers the vast majority of the papers in this research field. The *inclusion/exclusion selection criteria* of any systematic literature review must be clear and well-defined, because they facilitate the procedure of the study selection. The selection criteria of the present systematic review are shown below:

The *quality assessment criteria* are defined to ensure that all the included studies in a systematic literature review attain an acceptable level of quality. The search string that was used in the present literature review is shown in Figure 1. All the searches are based on the title, the abstract and the keywords of the papers in order to avoid receiving a huge number of irrelevant papers as search results. From 33194 papers with the keywords of "*Disaster management*" 2636 papers are about "*Evacuation*" and it is filtered to 2161 papers with the subject of "*Emergency evacuation*". From these articles 47 papers are related to maritime, 63 papers are about aviation and aircraft, 44 papers subjected to railways and 668 papers are covering building and construction emergency evacuation events. The other documents are not considered because their main subjects are general emergency evacuation, general health care after emergency evacuation and nursing.

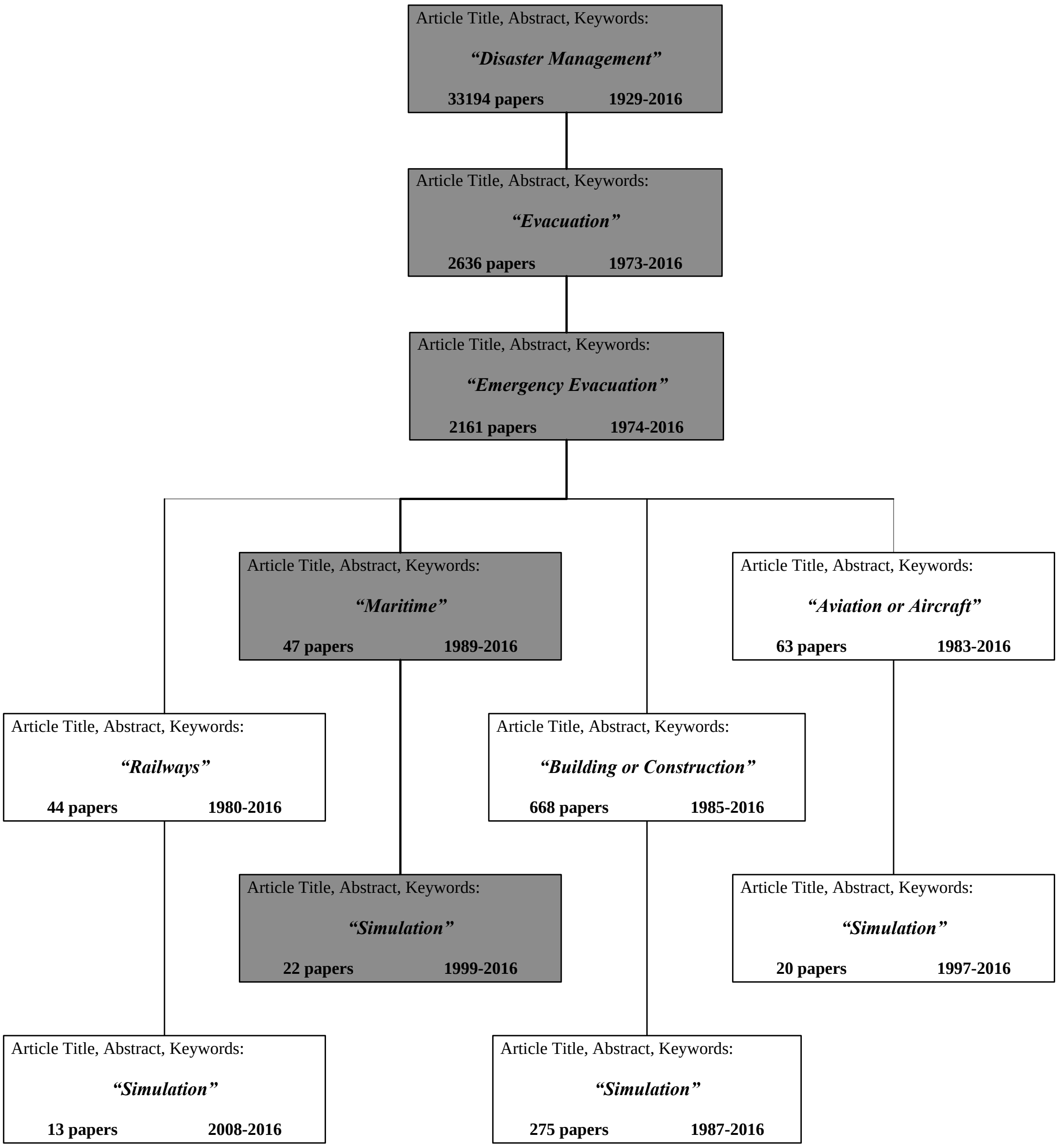

Figure 1. The search string using "And" and "Or"

In the present literature review, the criteria for a paper to be included in the study regard the availability and the description of the data, the description of the used methodology and the presentation of the results. Papers that at least cover partially the above four criteria are included in the review. Finally, the last action related to the development of the review protocol is the ***analysis results and comparisons***. After the development of the review protocol, all the predefined steps of the systematic literature review are executed.

Specifically, after the initial search process, 47 papers were found. After the reading of titles and abstracts of the candidate papers, aiming to find irrelevant papers or duplicates, two papers were removed and the number of remaining papers became 45. Next, after the reading of full papers, 3 more papers were removed as irrelevant based on the inclusion/exclusion criteria. Hence, the final number of selected papers resulting from the broad automated search was 42.

As already mentioned, the backward snowball technique was subsequently applied and from the reading of the references, 5 more papers were added. Thus, the number of the papers after the entire study selection process was 47. Finally, these 47 papers cover either partially or completely the four quality assessment criteria described above and therefore, the concluding number of selected papers for our literature review is 47.

4. Results

Maritime emergency evacuation field has been evaluated related to disaster management. Based on the analysis, among 33194 papers with the subject of *"Disaster management"* between the years of 1929 to 2016, almost 47 papers those have been released from 1989 to 2016 are subjected to the "*Maritime*". As shown in the figure 2. Engineering area with 17 articles is the most interested area about the maritime emergency evacuation. Shanghai maritime university is the most active institution on the field of the maritime emergency evacuation with 9 documents. The United States of America, China and Iran are the most active countries on the field of the maritime emergency evacuation.

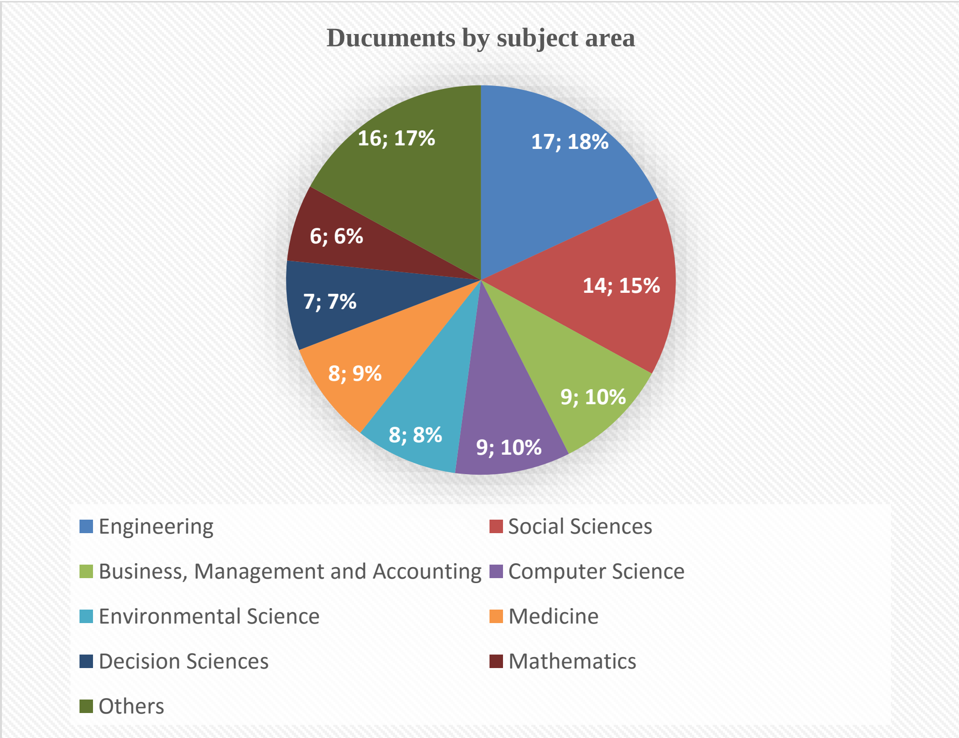

Figure 2. The pie chart showing search results analysis

The most important extracted point from this pie chart is the **social science** area that is being interested in emergency maritime evacuation event.

On February 2nd 1987, the engine of the tanker O.T. Garth carrying 28,000 t of leadless gasoline exploded and the ship ran aground in the bay of Seine. The first call mentioned several dead and about ten wounded-burned persons. The SAMU 76B sent 3 medical staffs with their equipment, allowing a correct **management** of the victims. The **evacuation** of the victims was made in debatable conditions by motor launch and helicopter. Based on this the first document on emergency maritime evacuation released by Bigo M. et al., (1989). They tried to analysis 1) the behavior of the different responsible (CROSS, semaphore of French Navy, Le Havre harbor authorities, **maritime** and terrestrial authorities, fire brigade, SAMU (**emergency** medical service)); 2) the problems of coordination between **emergency** schemes according to SECMAR instructions, ministerial instructions of 1983 and the reality of operational necessities; 3) the necessity of possible local coordination of the **emergency** aid organizations because the local level is the one which will allow a correct **management** of the medical, technical or meteorological constraints (BIGO et al., n.d.).

The difficulties and injuries sustained during the emergency evacuation of 308 passengers and crew from the fast passenger catamaran M.V. St Malo injured fifty-three passengers (Lockey et al., 1997) and this inspired Lockey et al. (1999) to recommend increasing of numbers of emergency exits and the introduction of evacuation chutes to this type of twin-hulled vessels. Gwenne et al., (1999) have mentioned that Computer based analysis of evacuation can be performed using one of three different approaches, namely optimization, simulation or risk assessment. Furthermore, within each approach different means of representing the enclosure, the population, and the behavior of the population are possible. The myriad of approaches which are available has led to the development of some 22 different evacuation models. This article attempted to describe each of the modelling approaches adopted and critically review the inherent capabilities of each approach (Gwynne et al., 1999).

Chengular et al. (1999), mentioned that “the presence of the Internet and the World Wide Web provide the infrastructure for creating an inter-organizational information system”. They proposed an ad hoc forecast based on the ad hoc analysis that is a business intelligence process designed to answer a single, specific business question. The product of ad hoc analysis is typically a statistical model, analytic report, or other type of data summary (Chengalur-Smith, Belardo, & Pazer, 1999). IMO started to develop guidelines for more detailed simulation tools for analyzing evacuation from passenger ships (Glen & Galea, 2001). Consequently Glen and Galea released a paper that was describing the development of such a tool and aspects associated with the collection of marine specific human performance data. The work by Heinrich Soding (Söding, 2002) discussed the problems such as, in order of increasing sophistication: cross-flooding of damaged compartments; evacuation of persons on board a ship; sinking of a damaged ship in still water; accelerations and loads on free-fall lifeboats and damaged ship survival time in a seaway. Vassalos et.al, mentioned that evacuability represents a risk measure of passenger evacuation at sea (Vassalos, Christiansen, & Kim, 2002), and they expressed it as an index.

Boulougouris and Papanikolaou, described the methodology utilized by the code EVDEMON (EVacuation DEmonstration & MOdeliNg), what was under development at SDL-NTUA, for the simulation of the evacuation process onboard passenger ships and presents typical results of application to the evacuation of a modern Ro- Ro passenger ferry. The code was understood as a design tool assisting the designer in the early design stage as to the consideration of proper arrangements for enabling a timely and safe evacuation. The designer was asked to care of optimal measures in terms of internal arrangements to allow for the fast evacuation without bottlenecks, when the ship was in danger (Boulougouris & Papanikolaou, 2002). The paper by Lee et al. (2003), reviewed the requirements of the IMO and was regarding ship evacuation (Lee, Kim, Park, & Park, 2003). Also the applicable evacuation models was presented by Kim et al. (2004) Also several experimental methods to obtain data of human behavior with consideration to ship list and dynamics were evaluated at their paper (Kim et al., 2004). Another work by Lee and his colleagues emphasized that walking speed is a very important factor in evacuation analysis for human safety (Lee et al., 2004). They mentioned at their paper that, onboard experiments were carried out twice, once with ship motion and another without ship motion. Park et al. (2004), summarized different features of the evacuation models as ‘‘the integration of intelligent human behavior model and dynamics model’’(Park, Lee, Kim, & Yang, 2004).

Pineiro et al. (2005), tried to present the conceptual design, models and user oriented software tools developed to apply the IMO passengers evacuation rules in an automatic way (Donoso & Torres, 2005). Another paper by Vanem and Skjong describes a set of well-defined evacuation scenarios for use in advanced evacuation analyses of passenger ships according to the maritime safety regulations (Vanem & Skjong, 2006). Supporting by european community Wallingford conducted a review of evacuation rescue methods and models (Wallingford, 2006).

The paper by Vanem and Skjong., (2006) describes a novel set of well-defined **evacuation** scenarios for use in advanced **evacuation** analyses of passenger ships according to **maritime** safety regulations. The scenarios are based on a recently performed risk assessment of passenger ship **evacuation** and can be related to actual accident scenarios, covering the major hazards passenger ships are exposed to. Furthermore, a risk-based methodology for using the set of scenarios in **evacuation** performance evaluation is proposed and it is demonstrated how the scenarios can be used to relate actual design options to the overall level of risk associated with the ship (Vanem & Skjong, 2006).

Altay and Green (2006) investigated the literature to identify potential research directions in **disaster** operations (Altay & Green, 2006). The paper by Siu, N. (2006) addressed a number of PRA (Probabilistic Risk Assessment) applications in support of **emergency** preparedness, response, recovery, reconstitution, and analysis activities. This paper also identifies gaps in PRA applications (e.g., lack of models to address problems in inter-organizational coordination and communication) that are likely to be important obstacles in the development of a fully risk-informed approach to **emergency management**, and identifies promising work that, upon completion, may be able to address some of these gaps. Brown et al. (2008) outlined experiments conducted to quantify human performance during abandonment using a variety of life saving appliances for ambulatory and non- ambulatory individuals wearing personal floatation apparatus. Evacuation analysis using commercially available software with these data was also presented as it relates to improving ship design for evacuation of non- ambulatory persons . Lozowicka and Czyz, purposed a method for calculating of evacuation time, they used two macroscopic (simplified) models and microscopic (advanced) models for evacuation analysis (Eksploatacji, 2008). Deere et al. (2009), presented a systematic and transparent methodology for assessing the HF (Human Factors) performance of ship design which was both discriminating and diagnostic (Deere, Galea, & Lawrence, 2009).

Pitana and kobayashi presented a systematic and transparent methodology for assessing the HF performance of ship design which is both discriminating and diagnostic (Pitana & Kobayashi, 2009). Machado Tavares and Galea presented a methodology which combined the use of evacuation models with numerical techniques used in the operational research field, such as Design of Experiments (DoE), Response Surface Models (RSM) and the numerical optimization techniques. The methodology here presented was restricted to evacuation modelling analysis. Meanwhile the authors concluded that “this same concept can be extended to fire modelling analysis” (Tavares & Galea, 2009). Cai et al. (2010), at their paper aimed to provide a framework for determining the optimal combination of ventilation and evacuation strategies by considering the uncertainty of source locations (Cai, Long, Li, Kong, & Xiong, 2010).

Ginnis et al (2010)., focused on the novel features of VELOS (Virtual Environment for Life on Ships) related to both its VR (Virtual Reality) and evacuation-specific functionalities (Ginnis, Kostas, Politis, & Kaklis, 2010). Klupfel at his paper dealt with various aspects of ship evacuation: Guidelines, Simulation, Validation, and Acceptance Criteria (Klupfel, 2010). Lozowicka at his paper titled by “Problems of opposite flow of people during evacuation from passenger ships” that was proposed to search for the critical value of density depending on the number of persons moving in the opposite direction (Morska & Łozowicka, 2010). Vanem and Ellis`s challenge was an evaluation of the cost-effectiveness of a novel passenger monitoring system based on RFID technology for implementation onboard passenger ships (Vanem & Ellis, 2010). Zheng and Liu proposed a forecasting model that this model not only reflects the complexity and dynamics of evacuation process but also performs an accurate forecasting on the time development of the pedestrian distributed in the evacuation space (Zheng & Liu, 2010). The work of Azzi et al. (2011), makes use of integration of fire simulation and evacuation modelling in order to assess the safety performance of passenger ships when critical fire scenarios occur (Azzi & Pennycott, 2011).

Golmohammadi and Shimshak (2011) proposed a prediction model to estimate the evacuation time in an emergency situation (Golmohammadi & Shimshak, 2011). Liu and Qiu introduced a secondary evacuation planning problem which was solved by computing flow-dependent shortest path through a known shortest time escape route on a ship (C. Liu & Qiu, 2011). Sagun et al. (2011), conducted a crowd simulation for improving the design of the built environment and guidelines in their paper (Sagun, Bouchlaghem, & Anumba, 2011). Ha et al. (2012), presented a simulations of advanced evacuation analysis using a cell-based simulation model for human behavior in a passenger ship. The cell-based simulation model is dividing the space in a uniform grid called cell (Ha, Ku, Roh, & Lee, 2012). Hansen et al. (2012), published a work with the title “Factors influencing survival in case of shipwreck and other maritime disasters in the Danish merchant fleet since 1970” (Hansen, Jepsen, & Hermansen, 2012). Purpose of the work by Harwood and Farrrow (2012) was the validation of factors associated with the adverse outcomes prerecorded by themselves in 2008 during vertical chute MES (Marine Evacuation Systems) training, and to assess the hypothesis that evacuee’s clothing material will affect the efficiency of the system (Harwood & Farrow, 2012).

Koo et al. (2012), studied how seriously residents with disabilities affect the evacuation of other residents in a 24-story high-rise building environment through an agent-based simulation model. They presented regression models and controlled evacuation strategies that help evacuation administrators ensure the safe evacuation of all the residents by controlling the number of residents and evacuate residents with disabilities efficient (Koo, Kim, & Kim, 2012). Zainuddin and Aik (2012) proposed a refined cellular automata model which applied to simulate the crowd movement of Muslim pilgrims performing the religious ritual within the Al-Haram Mosque in Mecca. The results from the simulation are obtained and the influence of the predictor variables of the evacuation process (pedestrian flow and Tawaf duration) on the responses (pedestrian density, average walking speed, and cumulative evacuee) is investigated using response surface methodology (RSM) (Lim & Zainuddin, 2012). Manley and Kim, in their paper, presented a public decision support system (DSS) distinguished from various DSSs in the private business sector in terms of its ownership, data scarcity, and beneficiaries (Manley & Kim, 2012).

The work of Tissera et al., shows a computer simulation in order to specify and implement a simulation model that allows to investigate behavioral dynamics for pedestrians in an emergency evacuation. they present a hybrid model where the dynamics of fire and smoke propagation are modelled by means of Cellular Automata and for simulating people behavior they are using goal oriented Intelligent Agents (Tissera, Printista, & Luque, 2012). Wang and Song proposed a new analysis method based on improved response (IRS), which constructed by uniform design (UD) and non-parametric regression (NR), and then, obtained the available safety egress time (ASET) and the required safety egress time (REST) probability distribution with Monte Carlo simulation (Xiaowen Wang & Zhigang Song, 2012). Wu Chu et al. (2013), used mathematical programming as the research methodology in their study. They formulated the model and explored different evacuation scenarios, then compared the results from their minimum cost flow model with that of original evacuation plan (Chu, Lu, & Pan, 2013). Goodwin and Granmo, reported that how an Ant Colony Optimization (ACO) pathfinding algorithm could possibly be used to lead passengers out of this dangerous situation (Goodwin & Granmo, 2013).

In the work of Ha et al. (2013), a simulation for passenger ship evacuation considering the inclination of a ship is presented. In order to describe a passenger's behavior in an evacuation situation, a passenger is modeled as a rigid body which translates in the horizontal plane and rotates along the vertical axis (Ha, Namkug, & Roh, 2013). In the study of Lv et al. (2013), an interval-parameter joint-probabilistic integer programming (IJIP) method is developed for emergency evacuation management under uncertainties (Lv et al., 2013). Nguyen et al. (2013), in their paper present an agent-based evacuation model with Smoke Effect and Blind Evacuation Strategy (SEBES) which respects that recommendation by integrating a model of smoke diffusion and its effect on the evacuee's visibility, speed, and evacuation strategy (Nguyen, Ho, & Zucker, 2013). Osman and Ram (2013) , presented a Two-phase evacuation route planning approach using combined path networks for buildings and roads (Osman & Ram, 2013). Roh and Ha (2013) presented an advanced ship evacuation analysis as a stochastic methods in which the total evacuation time is calculated via computer-based simulations, by considering each passenger's characteristics (Roh & Ha, 2013). Sarshar et al. (2013), presented an evacuation model for ships while a fire happens onboard. The model is designed by utilizing Bayesian networks (BN) and then simulated in GeNIe software (Sarshar J. Radianti, O-C. Granmo, and J. J. Gonzalez, 2013). Tissera et al. (2013), proposed a model which has a hybrid structure where the dynamics of fire and smoke propagation are modelled by mean of Cellular Automata and for simulating people's behavior they use Intelligent Agents. The simulation model consists of two sub-models, called pedestrian and environmental (Tissera, Castro, Printista, & Luque, 2013). Zhang et al. (2013), proposed a probabilistic occupant evacuation model for fire emergencies using Monte Carlo methods and then integrates the model into the fire risk analysis model CUrisk (Zhang, Li, & Hadjisophocleous, 2013). In Akyuz & Celik (2014), human factors analysis is used and classification system (HFACS) is combined with cognitive map (CM) in marine accident analysis. The HFACS–CM model is recognized as hybrid accident analysis approach provides distribution of human error by taking the operational evidence into account (Akyuz & Celik, 2014). Huang et al. (2014), proposed a for simulation study of evacuation in high-rise buildings (Huang, Chen, & Yuan, 2014). Jiang et al. (2014), conducted an investigation and simulation on human evacuation behavior in large hospital building in Shenyang (Jiang, Zhang, Shang, & Tian, 2014). Liu et al. (2014), proposed a unique simulation model for assessing aircraft emergency evacuation considering passenger physical characteristics (Y. Liu, Wang, Huang, Li, & Yang, 2014). Sakakibara et al. (2014), tried to reproduce a ship's behavior through a numerical simulation of the tsunami and the ship's motion (Sakakibara, Abe, Tsugane, & Kubo, 2014). Wang et al. (2014), proposed an agent-based microscopic evacuation model—CityFlow-M has been introduced by a passenger ship evacuation case, and then validated using data sets from a semi-unannounced assembly trail at sea, which consists of passenger response times, starting locations, ending areas as well as the arrival times in the assembling stations (Wang, Liu, Lo, & Gao, 2014). Xie et al. (2014), proposed an arbitrary polynomial chaos-based approach to analyzing the impacts of design parameters on evacuation time under uncertainty(Xie, Lu, D., & J., 2014). Ding et al. (2015), work was based on computer modeling and simulation, the problem of evacuation strategies that utilized a combination of stairs and elevators for high rise buildings (Ding, Yang, Weng, Fu, & Rao, 2015). Matsuura and Iwanaga developed a simulation model of ships that was setting sail from the port in order to evacuate from the tsunami considering the ship carrying dangerous goods (Matsuura & Iwanaga, 2015). Tan et al. (2015), suggested an Agent-based simulation of building evacuation combining human behavior with predictable spatial accessibility in a fire emergency(Tan, Hu, & Lin, 2015).

5. Conclusions

Due to lack of sufficient literature review studies that investigate emergency evacuation. This paper offered a review of the literature on maritime emergency evacuation during the period from 1940 to 2016. This paper reviewed the identify and explore patterns and trends in publication outlets; collect, document, scrutinise and critically analyse the current literature on this field; to identify gaps in the literature. To accomplish this task, the data from specialist academic journals, conference papers and technical reports of agencies are collected, reviewed and summarized based on a systematic review approach. Distributions of studies with respect to method, publication year, document type and country are proposed. Considering the Figure 1. and literature review based on the methods, almost half of the maritime emergency evacuation researches are based on simulation technics and at the recent years the simulation approaches turned to the only evaluation technics for emergency evacuation analysis. Different simulation models and approaches are insisting on the reality of passenger behavior and human performance during abandonment. Escape time while emergency situation is the matter of optimization which is crucially related with passenger run time, doors and corridors widths, trim and tail balance, egress time probability distribution, hybrid structure where the dynamics of fire and smoke are happened and a lot of other factors.

For the future works we will propose a systematic maritime exodus which will considered different types of evacuation scenarios to obtain the best emergency escape plan based on person behavior, fire and smoke behavior, physical properties of passengers, geometric properties of vessels and danger data. For determining drain discharge performance factors (The number of casualties and evacuation time) we will perform a statistical analysis.

Acknowledgements

This research was carried out as a part of The Scientific and Technological Research Council of Turkey (TUBITAK)-3001 project under the Grant agreement no 215M246.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Operators' Assignment in Cellular Manufacturing Systems: A Review of Recent Applications

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Abstract

As an outstanding manufacturing technology, cellular manufacturing is known as a useful approach for improving efficiency in industrial processes. Implementation of this approach requires indispensably considering various issues such as cell formation, cell layout of machines within cells/cells within shop floor, part scheduling in cells and resource assignments. Various researches can be found in the literature discussing them individually or together. Additionally, especially in the recent years, as a part of resource assignment problem, operators' assignment to cells is also necessarily taken into account for successful implementation of this approach. As a prominent component of this process, operators' assignment strategies are investigated in detail. This study aims to give useful insight into the human factors, in terms of allocation of the workers to cells, as a critical issue in order to form cells in cellular manufacturing environment. An overview of foremost applications of operator assignment strategies in cellular manufacturing literature is given based on a comprehensive review. The studies in the recent years are classified according to the constraints, assumptions, objective functions and solution techniques used. Finally, the assessments are summarized and potential research areas in this aspect are highlighted.

Keywords

Cellular manufacturing, worker assignment, cell formation, human factors

1. Introduction

Group technology is defined as "a manufacturing philosophy that attempts to provide some benefits of assembly line systems such as higher throughput rate, lower work in process etc., while maintaining some advantages of job shop such as flexibility of operations routing, larger product mix etc." (Vakharia, 1986). Cellular Manufacturing Systems (CMS) is an application of group technology to production systems by considering similarities between parts. Cell formation (CF), Cellular Layout (CL), Part Scheduling in Cells (CPS) and Resource Allocation (RA) are critical decisions in CMS (Zeng et al., 2015). By considering the similarities in the manufacturing processes, CF groups parts with similar operations in the same cell. To form the cells, most attention is given to maximize the utilization of the machines, minimize the cost of inter/intra-cellular movements, exceptional elements and the voids. CL is defined as determining the layout of machines within cell and layout of cells within the shop floor. CPS is the way of assignment and sequencing of the parts on available machines. RA technique determines the assignment of tools, human and material resources into cells.

The advantages of CMS are stated in the literature (Solimanpur et al., 2004) such as: "decreased setup times, reduced work-in-process inventories, improved product quality, shorter lead times, reduced tool requirements, improved productivity, better quality and production control, increment in flexibility, and decreased material handling cost." The issue of CF has widely been investigated in the literature and researchers have noticed potential benefits when the other CMS decisions are simultaneously considered. In the recent literature, there are many studies have paid attention to CF decisions (Dalfard, 2013; Nouri & Hong, 2013; Paydar & Saidi-Mehrabad, 2013; Saeidi et al., 2014; Zeb et al., 2016) but, relatively few works consider two or more CMS decisions together such as CF & CL (Javadi et al., 2013; Kia et al., 2014); CF, PCS (Eguia et al., 2013; Tang et al., 2014); CF, CL & PCS (Arkat et al., 2012).

Although Cellular manufacturing literature includes a number of research instances related to CF, CL, CPS and RA, as an important aspect of RA, human issues are mostly neglected. "While cellular manufacturing is a popular research area, there is a singular absence of articles that deal with the human element in cellular manufacturing. There are a variety of reasons for this including that these issues are typically difficult to quantify. It has been well documented that there is an absence of research in the area of worker placement based on both their technical and human skills" (Bidanda et al., 2005).

This study is aimed to give deeper analyzing operators' assignment in CMS as the reference to other researchers. The reminder of the paper is organized as follows. In section 2, the constraints and assumptions in CMS are presented. In section 3, Operator Assignment Issues in CMS are explained and classifications according to the constraints, objective functions and the solutions techniques used are given. The conclusions and possible future researches are given in section 4.

2. Constraints and Assumptions in CMS

Some constraints and assumptions affect the structure of a CMS directly and indirectly available for forming the CMS problems in the related studies can be classified in six groups.

2.1. Parts Related Constraints/Assumptions: processing time of each part operation in each machine (deterministic/stochastic), route flexibility, demand fluctuations, production volume of part, process plan for each part, particular machine tool requirements of some part operations, alternative routing, type of tools required by a part, sequence of operations.

2.2. Machine Related Constraints/Assumptions: machine flexibility, machine capacity, machine breakdowns, types of tools available on a machine, setup time, addition or removal of machines to any cell or relocation of machines from one cell to another between periods, proximity constraints (separation/collocation), type of tools available on a machine.

2.3. Operator Related Constraints/Assumptions: min/max number of responsible worker to process a part operation, available working time, availability of different workers doing same jobs, the importance of the skill level of workers for layoffs, training to upgrade the skill level of workers, productivity and skill levels of workers, dismissal recruitment and training to ensure the realization of the total demand, firing and hiring of workers to response demand fluctuations, workload balancing, operator allocation.

2.4. Cell Related Constraints/Assumptions: the number of cells to be formed (deterministic/stochastic), assignment of parts/machines/workers to only one cell, upper and lower limits for the number of workers/machines/parts to be assigned to each cell, dynamic cell reconfiguration.

2.5. Production Related Constraints/Assumptions: demand of each part in each period, parts availability at the beginning of the planning period, conservation of the parts between two consecutive periods, conservation of the total number suitable machinery between periods, conservation of the number of workers between periods.

2.6. Cost Related Constraints/ Assumptions: subcontracting costs, inventory holding and backorder costs between periods, relocation costs such as transportation and installation, maintenance costs, training costs to move from one skill level to another, machine investment costs, intracellular and intercellular movement costs, worker's salary dependency to the skill level, processing, preparation and tool consumption costs, setup cost.

3. Operator Assignment Issues in CMS

Although there has been relatively little research on operator assignment problem together with cell formation problem, an increasing trend on this area appears in the recent literature recently.

In cellular manufacturing systems, there are two categories includes manned cells and unmanned cells. Although unmanned cells are seemed to be ideal, due to advanced technology requirements and investment costs they are not widespread enough. In manned cells, machine loading, parts handling, tooling, machinery preparation activities are under control of the operator. So, assignment of workers to machines and cells are critically important for construction of cells. The strategy for assignment of operators to cells and/or machines are decided by considering operator's skills, their education, their relationship with each other, teamwork skills, etc. (Bidanda et al., 2005). Thus, workload sharing will be provided by increasing the efficiency of the workforce. Additionally, increasing the average utilization rate and balancing the workload of operators also provide increasing on overall performance of the cell. Cesaní and Steudel (2005) studied inter-cell operator's mobility to consider labor flexibility in CMS. Labor assignment strategies including "dedicated", "shared" and "combined" assignments are considered. In the study of Norman et al. (2002), to change skill levels of workers are permitted through providing additional training.

Vast majority of cell formation problems deal with the two-dimensional structure based on the assignment of parts and machines to cells. However, the degree of operator’s ability working on machines significantly affects the performance of cellular manufacturing. Min and Shin (1993) added operator factor into part-machine relationship matrix as the third dimension for the first time. N-dimensional GT was proposed by Parkin and Li (1997). Li (2003) proposed a method for solving multi-dimensional GT problem and so, all incidence matrices could be considered simultaneously. Mahdavi et al. (2012) developed a mathematical model that considers a three-dimensional machine-part-worker incidence matrix.

The operator assignment literature studies in recent years have been examined in detail and the results have been evaluated in the following sections. Some of the studies consider operator assignments are also classified according to their constraints and objective functions in Table 1 and Table 2.

In Table 1, in terms of system specializations, besides single period planning, some researchers considered the dynamic cellular manufacturing system by taking into account a multi-period planning. Machine related issues mainly include machine flexibility, machine capacity, machine breakdown/reliability, and identical/unrelated machines. Machine flexibility refers to the ability of each machine type for performing one or more operations. Machine capacity is the available limited time of the machines. It has influence upon the ultimate solution of the problem by taking into account the production volume and the time limitations. Part related issues consist of operation sequence, routing flexibility, processing time, and demand fluctuations. Routing flexibility is defined as each operation can be done on one or more machine types with different times (Aryanezhad et al., 2009). Operator related issues include flexibility of workers, worker skill levels, and interaction between workers. Generally, workers can only be assigned to machine levels that they can work.

The objective functions of the studies consider operator assignment issues are reviewed and summarized in Table 2. Most leading part related objective functions include holding, backordering, production, part quality, stockout and inter/intra cell movement costs, exceptional elements and voids. Machine related costs consist of breakdown/maintenance, purchasing, operating, balancing machine workload, and machine relocation costs. Operator related issues include labor utilization, hiring, firing, overtime, training costs and salaries.

Table 1. Constraints based classification for operator assignment literature

	System			Machine Related					Part related				Operator Related		
Reference	**Single Period**	**Multi Period**		**Machine Flexibility**	**Capacity**	**Breakdown Reliability**	**Identical Machines Machine Duplication**		**Operation sequence Routing flexibility**	**Processing Times**	**Demand Issues**		**Workers Flexibility Worker skills**	**Available time of workers**	**Interaction between workers, operator sharing**
Mahdavi et al. (2009)		√									√		√		
Aryanezhad et al. (2009)		√		√					√		√		√		
McDonald et al. (2009)					√					√			√		
Mahdavi et al. (2010)		√			√	√	√			√	√		√	√	
Mahdavi et al. (2011)		√								√	√		√	√	
Ali Azadeh et al. (2011)	√										√		√		
Mahdavi et al. (2012)	√												√		
Nikoofarid and Aalaei (2012)		√			√					√	√		√	√	
Rafiei and Ghodsi (2013)		√			√					√	√				
Aalaei and Shavazipour (2013)	√				√					√	√		√	√	
Süer et al. (2013)		√								√	√		√		√
Bootaki et al. (2014)	√												√		
Bagheri and Bashiri (2014)		√							√		√		√		
Mahdavi et al. (2014)	√												√		√
Egilmez et al. (2014)															
Bootaki et al. (2015)		√			√					√	√		√	√	
Mehdizadeh and Rahimi (2016)		√					√				√		√		
Liu et al. (2016)	√								√	√			√		

Table 2. Objective function based classification for operator assignment literature

Reference	**Part Related**						**Machine Related**					**Operator Related**	
	Holding	**Backordering**	**Production**	**Part quality**	**Stockout**	**Inter/İntra cell movements Voids/EE***	**Breakdown/ Maintenance**	**Purchasing**	**Operating**	**Balancing workload**	**Machine relocation**	**Labor utilization**	**Hiring, firing, training overtime, salary**
Mahdavi et al. (2009)	√				√								
Aryanezhad et al. (2009)			√			√		√			√		√
McDonald et al. (2009)	√			√									√
Mahdavi et al. (2010)	√	√				√	√				√		√
Mahdavi et al. (2011)	√	√				√							
Ali Azadeh et al. (2011)												√	
Mahdavi et al. (2012)						√							
Nikoofarid and Aalaei (2012)	√	√											
Rafiei and Ghodsi (2013)	√					√		√	√		√	√	√
Aalaei and Shavazipour (2013)	√	√				√				√		√	
Süer et al. (2013)												√	
Bootaki et al. (2014)				√		√							
Bagheri and Bashiri (2014)	√					√					√		√
Mahdavi et al. (2014)						√							
Egilmez et al. (2014)													
Bootaki et al. (2015)						√				√		√	
Mehdizadeh and Rahimi (2016)						√		√	√		√		√
Liu et al. (2016)						√	√		√				√

*EE: Exceptional Elements

As seen in Table 1, by taking into account the demands of real-life changes between periods, an increase in dynamic systems stand out in operator assignment literature. As Paydar et al. (2013) state: "In dynamic environment a multi period planning horizon is considered and each period has different product mix and demand requirements. So, the formed cells in a period may not be optimal compared to the next period." In terms of machine related issues, the most studied constraints are the machine capacity, as well as the identical machines and machine breakdowns. The processing time and fluctuations in demand for parts have also been included in the mathematical models. Processing sequence and route flexibility are also available in the relevant literature. The prominent feature on assignment of operators is operator flexibility that means an operator is capable to work on different machines. Operator flexibility and operator working time constraints are the topics which are also included in the model in studies in recent years. Additionally, few works take into account the interaction between workers.

From Table 2, in terms of part related objective functions, the most leading issues are minimization of voids and exceptional elements and also inter-cell material movements. In most of the studies, holding and backordering costs are tried to be minimized. One of the new topics in operator assignment literature is the consideration of part quality. Very limited studies have considered this subject. In terms of machine related objective functions, relocation and purchasing costs are stand out, especially because of the multi period planning. Besides, operating and balancing of machines are the other leading goals. Operators related objective functions include the minimization of the costs such as of hiring, layoffs, salary, training and education and also maximization of labor utilization.

Table 3. Solution Technique based classification for operator assignment literature

Solution Technique	**References**
Mathematical model	Aryanezhad et al. (2009); McDonald et al. (2009); Mahdavi et al. (2010); Mahdavi et al. (2011); Mahdavi et al. (2012); Nikoofarid and Aalaei (2012); Aalaei and Shavazipour (2013); Süer et al. (2013); Bagheri and Bashiri (2014); Mahdavi et al. (2014); Egilmez et al. (2014); Bootaki et al. (2015)
Mathematical Model & GA	Mahdavi et al. (2009)
Hybrid GA	Ali Azadeh et al. (2011)
Mathematical Model & a hybrid ACO-GA algorithm	Rafiei and Ghodsi (2013)
Mathematical Model & a Hybrid GA-AUGMECON	Bootaki et al. (2014)
Mathematical Model & MOSA & MOVDO	Mehdizadeh and Rahimi (2016)
Mathematical Model & DBFA & GA	Liu et al. (2016)

GA: genetic algorithm, MOSA: multi-objective simulated annealing, MOVDO: multi-objective vibration damping optimization algorithm, DBFA: discrete bacteria foraging algorithm

In Table 3, the studies have been examined in terms of the solutions techniques used. It should be noted that noticed that a mathematical model have been developed in order to get global optimum solutions for almost every problem. However, in these studies model performances have been investigated on small sized test problems which are not comparable with real life large sized case instances. The developed mathematical models are inadequate to find the global optimum solutions for large cases in a reasonable period of time with today's information technology and computer infrastructure. For this reason, an increase is seen recently in the number of heuristic approaches and algorithms.

Another important aspect is the multi objective nature of operator assignment problems. It is noticeable that in the most of the studies the objectives are combined by using scalarization methods. In some of the studies, goal programming (Bootaki et al., 2015; Satoglu & Suresh, 2009) and ε-constraint (Mahdavi et al., 2014) approaches have been taken into account to investigate Pareto solutions.

There are some also DEA based approaches with/without fuzziness in operator assignment literature. Ertay and Ruan (2005) proposed a new approach on data envelopment analysis (DEA) to decide optimal number of operators. A Azadeh et al. (2010) propose an integrated fuzzy DEA, fuzzy C-means and computer simulation for optimization of operator allocation in CMS. Park et al. (2014) decide the best operator allocation scenario by using a combination of GA, simulation and DEA.

4. Conclusions and Possible Future Researches

The following conclusions are derived from the recent operator allocation literature review:

- There is not any study in operator assignment literature, considering the required tools available for processing parts. Also, few works consider machine flexibility.
- Machine proximity includes separation and collocation constraints. Machines that cannot be located in a same cell due to technical and environmental requirements constitute separation constraint. Sometimes, because of using common resources, it is better to place two machines near each other and called collocation constraint. These constraints are not held in the operator assignment literature.
- The studies considering interactional interest are also limited in operator assignment aspect of CMS as stated by Mahdavi et al. (2014): "Human resources play an important role in manufacturing systems as they can affect the work environment. One of the most important factors impressing on worker performance is there being an interactional interest between workers in workshops."
- The psychological factors of the operators are another aspect of operator assignment problem which is ignored most probably because it is difficult to be modeled. Addition of these factors to models increases the validity of the model and serves as a better tool for system analysis and decision making.
- In the recent operator assignment literature, human issues include the issues of skill identification, training systems, but the topics including reward/compensation system, teamwork, and communication are still available to be studied.
- In particular, it has noticed that the ergonomic factors effecting the job environment and the operator's operating performance have not been involved in the problems. It is noteworthy that this area is open to investigate.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

An Optimization Approach for Balancing Multi Model Walking-Worker Assembly Systems

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Abstract

Walking worker assembly lines can be regarded as an effective method to achieve the below-mentioned characteristics. In such systems, workers, following each other, travel workstations in sequence by performing all of the required tasks of their own product. As the eventual stage of assembly line design, efforts should be made for capacity adjustments to meet the demand in terms of allocating tasks to workers via assembly line balancing. In this context, this study addresses the balancing problem for multi model walking worker assembly systems with the aim of improving planning capability for such systems by means of developing an optimization methodology. To the best knowledge of the author, workload balancing on multi model walking worker assembly lines with rabbit chase loop(s) has not yet been handled. Addressing this research gap, two linear integer programming models are proposed to balance multi model walking worker assembly line optimally in a sequential manner. The first mathematical programming model attempts to determine number of workers in each segment (i.e. rabbit chase loop) for each model. The second model generates stations in each segment to smooth workflow. The application of mathematical programming approach improved the performance of tap-off box assembly line in terms of number of workers (9.1%) and non-value added time ratio (between 27.9% and 26.1% for different models) when compared to a classical assembly system design.

Keywords

Walking-worker assembly systems, rabbit chase, optimization, busbar energy distribution system

1. Introduction

Companies need to improve their product range in order to meet the expectations of their customers for a higher level of customisation of the products. Therefore, consumer expectations as well as the requirements of production systems have changed enormously in many industries. Meanwhile, assembly systems (i.e. lines, cells) are commonly used in production systems, since they enable the high/medium-volume assembly of complex products with a satisfactory lead time performance (Masood, 2006). That assembly processes lead to %40 of total manufacturing cost and 15-70% of total manufacturing time emphasizes the importance of effectiveness for assembly line design and planning activities (Al-Zuheri et al., 2010). As one of the most significant assembly line design and planning activities (Ho and Emrouznejad, 2009), assembly line balancing (ALB) deals with the assignment of assembly tasks to the stations of the line without violating the precedence relations between the tasks, so that desired performance measures are satisfied (Yılmaz and Yılmaz, 2015; Agpak, 2010).

As for the workforce aspect, appropriate design for assembly systems have a significant effect on the worker performance, since the workers are the most valuable resources in these systems. In a classical assembly line/cell with stationary workers in each station, a balance in obtaining production pace among stations is often required. In addition, buffer is allocated among stations to decrease the effects of work imbalances (Al-Zuheri et al., 2013). That being the case, such a design not only increases production work-in-process and lead time, but also causes quality and communication problems. One effective method to avoid these drawbacks is to design walking worker assembly (WWA) systems. When, assembly tasks are finished for a product, the worker releases the product and moves back to the first station and receives a new product (Wang et al., 2009). This method is called rabbit chase (RC) since the working style of workers seems like chasing a rabbit (Suzaki, 1987). Meanwhile, it should be stated that rabbit chase loop can be executed for some segment(s) of the assembly system (i.e. partially) instead of overall system. Easier workload balancing, a reduced buffer requirement, a greater tolerance of work time variations, adjustability of the number of workers in response to the output requirement and more convenient environment for cross-training and communication can be provided by means of WWA systems (Cevikcan, 2014). Since each walking worker cannot be starved, individual labour utilization is increased in practice especially for manual (i.e. human-dominant) assembly systems. This advantage may lead to superiority of these systems over classical assembly systems in terms of number of workers. In addition, assembly systems with skilled walking workers can react to unpredictable conditions like varying production volumes or product mix (Wang et al., 2007). However, long walking distances and differences in worker skills may deteriorate the performance of WWA system applications. In addition, the feasibility of the WWA system applications depends on the nature of assembled products.

Taking into account the above-mentioned manners in manufacturing systems, this paper presents a novel optimization approach for multi model walking worker assembly systems. The inspiration for the research is the planning problem relating to the design and management of a real life busbar assembly system.

The remainder of this paper is organized as follows. Section 2 presents the developed mathematical programming approach. In Section 3, the application of the proposed methodology to a real life busbar production system is explained. Finally, conclusions are given in Section 4.

2. Mathematical Programming Approach for Multi Model WWAL

Mathematical programming models are provided for the integration of RC in multi model assembly lines in this section. two consecutive mathematical models are proposed in a hierarchical manner. The initial mathematical programming model (Model 1) determines the number of workers in each segment (i.e. RC loop) for each model. What is more, the number of stations and the distribution of station times in the segments is essential as far as effective workflow is concerned. Therefore, the following mathematical programming model (Model 2) generates stations in each segment so as to reduce idle and blocking times. Flowchart of the mathematical programming approach which integrates both of the models is given in Figure 1.

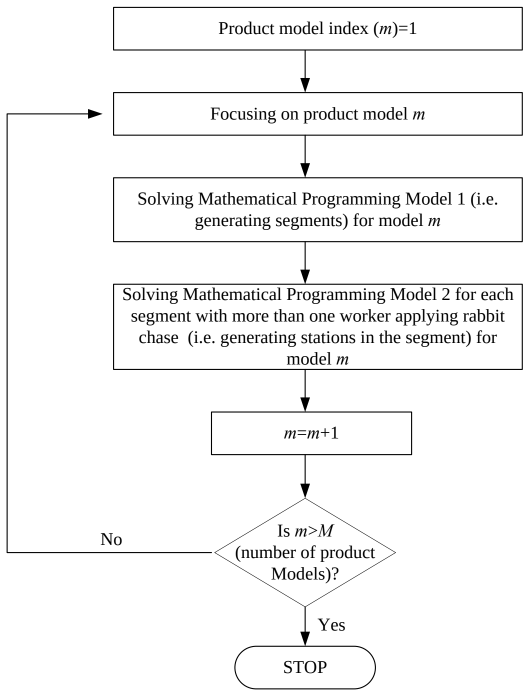


Figure 2: Mathematical programming approach

The formulation and detailed information about the mathematical programming models are presented in the following subsections.

2.1. Mathematical Programming Model 1

As can be seen in the third step of mathematical programming approach (Figure 2), this model is applied for each product model *m* with the aim of generating segments.

Indices

i: tasks
l: segments
k: workers
m: models

Parameters

C_m = Cycle time for model *m*
N_m= Number of tasks for model *m*
t_{im}= Total (processing and setup) time of task *i* for model *m*
w_k= Maximum total walking time for a segment including *k* operators
PR_{im}= The set of immediate predecessors of task *i* for model *m*
K= Maximum number of workers allowed in a RC

Variables

$$x_{ilm} = \begin{cases} 1; \text{if task } i \text{ is performed in segment } l \text{ for model } m \\ 0; \text{otherwise} \end{cases} \quad i=1,.., N \quad l=1,.., N$$

$$v_{lm} = \begin{cases} 1; \text{if segment } l \text{ is generated for model } m \\ 0; \text{otherwise} \end{cases} \quad l=1,\dots, N$$

$$z_{lkm} = \begin{cases} 1; \text{if } k \text{ workers perform rabbit chase in segment } l \text{ for model } m \\ 0; \text{otherwise} \end{cases} \quad l=1,\dots, N \quad k=1,\dots, K$$

Objective function

$$\text{Minimize} \sum_{l=1}^{N_m} \sum_{k=1}^{K} k \times z_{lkm} \tag{1}$$

Subject to

$$\sum_{l=1}^{N_m} x_{ilm} = 1 \qquad i=1,\dots, N_m \tag{2}$$

$$\sum_{l=1}^{N_m} l \times x_{ilm} - \sum_{l=1}^{N_m} l \times x_{flm} \geq 0 \qquad i=1,\dots,N \ \forall f : f \in PR_{im} \tag{3}$$

$$\sum_{i=1}^{N_m} t_{im} \times x_{ilm} + w_k \times \sum_{k=1}^{K} z_{lkm} \leq C_m \times \sum_{k=1}^{K} k * z_{lkm} \qquad l=1,\dots, N \tag{4}$$

$$\sum_{k=1}^{K} z_{lkm} = v_{lm} \qquad l=1,\dots, N \tag{5a}$$

$$x_{ilm} \leq v_{lm} \qquad i=1,\dots, N \qquad l=1,\dots, N \tag{5b}$$

$$v_{lm} - v_{dm} \geq 0 \qquad \forall (l,d) : 1 \leq l \leq N \wedge l < d \tag{6}$$

$$x_{ilm} \in \{0,1\} \qquad i=1,\dots, N \qquad l=1,\dots, N \tag{7a}$$

$v_{lm} \in \{0,1\}$ $\quad$ l=1,…, N $\quad$ (7b)

$z_{lkm} \in \{0,1\}$ $\quad$ l=1,…, N $\quad$ k=1,…, K $\quad$ (7c)

The objective function (1) minimizes the number of required workers among models in a walking worker MMAL. Constraints (2) provide that each task is assigned to only one segment. Constraints (3) satisfy the precedence relations among tasks for each model. Total assembly and walking time cannot exceed "cycle time$\times$ the number of workers" in a RC loop for each model via Constraints (4). Constraints (5) state the relation among segment generation, the number of workers in a segment (RC loop) (5a) and task assignment (5b). Constraints (6) provide generation of segments in a consecutive manner. Constraints (7) define the domains for variables.

2.2. Mathematical Programming Model 2

In the third step of mathematical programming approach (Figure 1), this model is applied for each segment where workers perform assembly tasks in a rabbit chase loop (i.e. number of workers in segment≥2) for model *m* with the aim of generating stations within segments.

A pre-emptive programming approach is preferred for Model 2. First, the number of stations is determined, then the throughput is maximized in each segment where RC is performed without deteriorating the solution in terms of number of stations so as to smooth workloads among stations.

Indices
i: tasks
j: stations
l: segments
m: models

Parameters
NRS_{lm}=Set of tasks in RC segment *l* for model *m*
NR_{lm}=The number of tasks in RC segment *l* for model *m*
NW_{lm}=The number of workers in the segment *l* for RC for model *m*
UBS_{lm}=Upper bound for the number of stations in the segment *l* with a given cycle time for model *m* (Scholl, 1999)

$$UBS_{lm} = \min\left\{ NR_{lm}; \left[\left[\left(\sum_{i\in NRS_{lm}} t_{im} - 1\right) / \left(C_m + 1 - \max_{i\in NRS_{lm}} t_{im}\right)\right] + 1\right]; \left[\left[(2 * \sum_{i\in NRS_{lm}} t_{im} - 2)/(C_m + 1)\right] + 1\right]\right\} \quad (8)$$

PRS_{ilm}=The set of immediate predecessors of task *i* in the same segment *l* for model *m*
C_m and t_{im} (defined in section 4.1)

Variables

$$y_{ijlm} = \begin{cases} 1; \text{if task } i \text{ is assigned to station } j \text{ in segment } l \text{ for model } m \\ 0; \text{otherwise} \end{cases} \quad i \in NRS_{lm} \quad j=1\ldots, UBS_{lm}$$

SR_{lm}=The number of stations in the segment *l* for model *m*
TR_{lm}=maximum of station times in the segment *l* for model *m*

Objective function-1

Minimize SR_{lm} $\quad$ (9)

Subject to

$$\sum_{j=1}^{UBS_{lm}} y_{ijlm} = 1 \qquad i \in NRS_{lm} \qquad (10)$$

$$\sum_{i \in NRS_{lm}} t_{im} \times y_{ijlm} \le C_m \qquad j=1,\ldots, UBS_{lm} \tag{11}$$

$$\sum_{j=1}^{UBS_{lm}} j \times y_{ijlm} - \sum_{j=1}^{UBS_{lm}} j \times y_{fjlm} \ge 0 \quad i \in NRS_{lm} \ \forall f : f \in PRS_{ilm} \tag{12}$$

$$j \times y_{ijlm} \le SR_{lm} \qquad i \in NRS_{lm} \qquad j=1,\ldots, UBS_{lm} \tag{13}$$

$$SR_{lm} \ge NW_{lm} \tag{14}$$

$$y_{ijlm} \in \{0,1\} \qquad i \in NRS_{lm} \qquad j=1,\ldots, UBS_{lm} \tag{15a}$$

$SR_{lm} \ge 0$ and integer (15b)

Objective function (14) minimizes the number of stations in the segment. Occurrence, cycle time, and precedence constraints are given in (15), (16) and (17), respectively. Constraints (18) determine the number of stations in the segment. Constraint (19) constructs the relationship between the number of stations and the number of workers in the segment. Constraints (20) define the domain for the variables.

Objective function-2

Minimize TR_{lm} (16)

Subject to

$$\sum_{j=1}^{SR_{lm}} y_{ijlm} = 1 \qquad i \in NRS_{lm} \tag{17}$$

$$TR_{lm} \le C_m \qquad j=1,\ldots, SR_{lm} \tag{18}$$

$$\sum_{j=1}^{SR_{lm}} j \times y_{ijlm} - \sum_{j=1}^{SR_{lm}} j \times y_{fjlm} \ge 0 \quad i \in NRS_{lm} \qquad \forall f : f \in PRS_{ilm} \tag{19}$$

$$\sum_{i \in NRS_{lm}} y_{ijlm} > 0 \quad j=1,\ldots,SR_{lm} \tag{20}$$

$$\sum_{i \in NRS_{lm}} t_{im} \times y_{ijlm} \le TR_{lm} \quad j=1,\ldots,SR_{lm} \tag{21}$$

$$y_{ijlm} \in \{0,1\} \qquad i \in NRS_{lm} \quad j=1,\ldots,SR_{lm} \tag{22a}$$

$TR_{lm} \ge 0$ (22b)

In the second phase of the pre-emptive programming model, the maximization of throughput (i.e. minimization of maximum station time) is provided via objective function-2 (16). Constraints (17), (18), (19) are denoted as occurrence, takt time and precedence constraints, respectively. Constraints (20) ensure that each of SR_{lm} stations are utilized for task assignment. Constraints (21) determine TR_{lm} as the maximum of station times in the segment. The domains for the variables are given in Constraints (22).Mathematical programming model 2 can be revised for classical assembly line balancing including non-walking workers. The term “segment” should be changed as “assembly line” and the parameter of NW_{lm}, index for segment (l) should be removed. In addition, N_m and PR_{im} in Model 1 should be used instead of NR_{lm} and PRS_{ilm}. In addition, upper bound should be determined for N_m tasks.

3. Industrial Application

The proposed mathematical programming approach was applied to a real life tap-off box assembly line in a busbar energy distribution system manufacturer. Busbar energy distribution systems respond to all kinds of power requirements with their modular configuration during both installation and operation in modern enterprises and buildings. Related information about the assembly tasks for tap-off box models is given in Table

1. The takt time is computed as 128 seconds with a daily demand of 225 tap-off boxes (KOP 250: 103 and KBP 160: 122). In addition, the maximum number of workers allowed in a RC (*K*) is decided as 3 by considering working segmentation, transportation activities and product size. Cycle times for KOP 250 and KBP 160 are 148 and 111.

Table 1: Time and predecessors for each assembly task

No	Task	KOP 250		KBP 160	
		Time (sec.)	Predec.	Time (sec.)	Predec.
5	Assembling connector plate blocks to main body	75	-	82	-
10	Pre-assembling contact group and placing to main body	18	-	20	-
15	Assembling bedding sheets to main body	55	10	52	10
20	Assembling hinges to main body	32	-	24	-
25	Assembling switch to main body	50	15, 40	61	15, 40
30	Attaching front connection bolts for switch	40	25	6	25
31	Pre-assembling phase components	80	-	N/A	N/A
35	Making phase connec. between switch and contact group	82	25, 31	18	25, 31
40	Assembling insulators to main body	20	-	50	-
45	Pre-assembling neutralization bar	30	25	40	25
50	Assembling neutralization bar	38	35, 45	17	35, 45
55	Tightening bolts for copper, switch and neutralization bar	32	50	26	50
60	Making torque control for bolts	27	55	25	55
65	Assembling arm shaft to main body	30	20	30	20
70	Assembling bearing sheet to main body	10	-	8	-
75	Pre-assembling cover plastic	50	-	40	-
80	Assembling cover plastic	26	30, 60, 65, 75	14	30, 60, 65, 75
85	Pre-assembling grounding bar into the main body	45	-	40	-
90	Making groove locking mechanism by reversing main body	40	65, 85	35	65, 85
95	Making contact control	13	10	20	10
100	Assembling grounding sheets to main body	33	-	26	-
105	Assembling leverage sheet	17	100	16	100
110	Assembling groove locking upper sheet	22	105	17	105
115	Assembling locking mechanism to cover	27	70, 80	7	70, 80
120	Assembling plastic handle to cover	26	115	16	115
125	Assembling grounding cable to cover	14	120	14	120
130	Assembling neutralization bar components to cover	34	125	34	125
135	Assembling cover to main body	71	90, 130	21	90, 130
140	Assembling grounding cable to main body	82	135	82	135
145	Labelling	20	140	20	140
150	Performing functionality test	60	95, 110	50	95, 110
155	Attaching groove locking lower sheet	84	150	78	150
156	Fixing connector and placing it into the box	38	155	N/A	N/A
160	Packaging	65	5, 145, 156	50	5, 145, 155

Task assignment among workers was implemented for classical assembly line (CAL), comprising one stationary worker for each station, as given in Table 2.

Table 2: Classical line balancing for tap-off box assembly

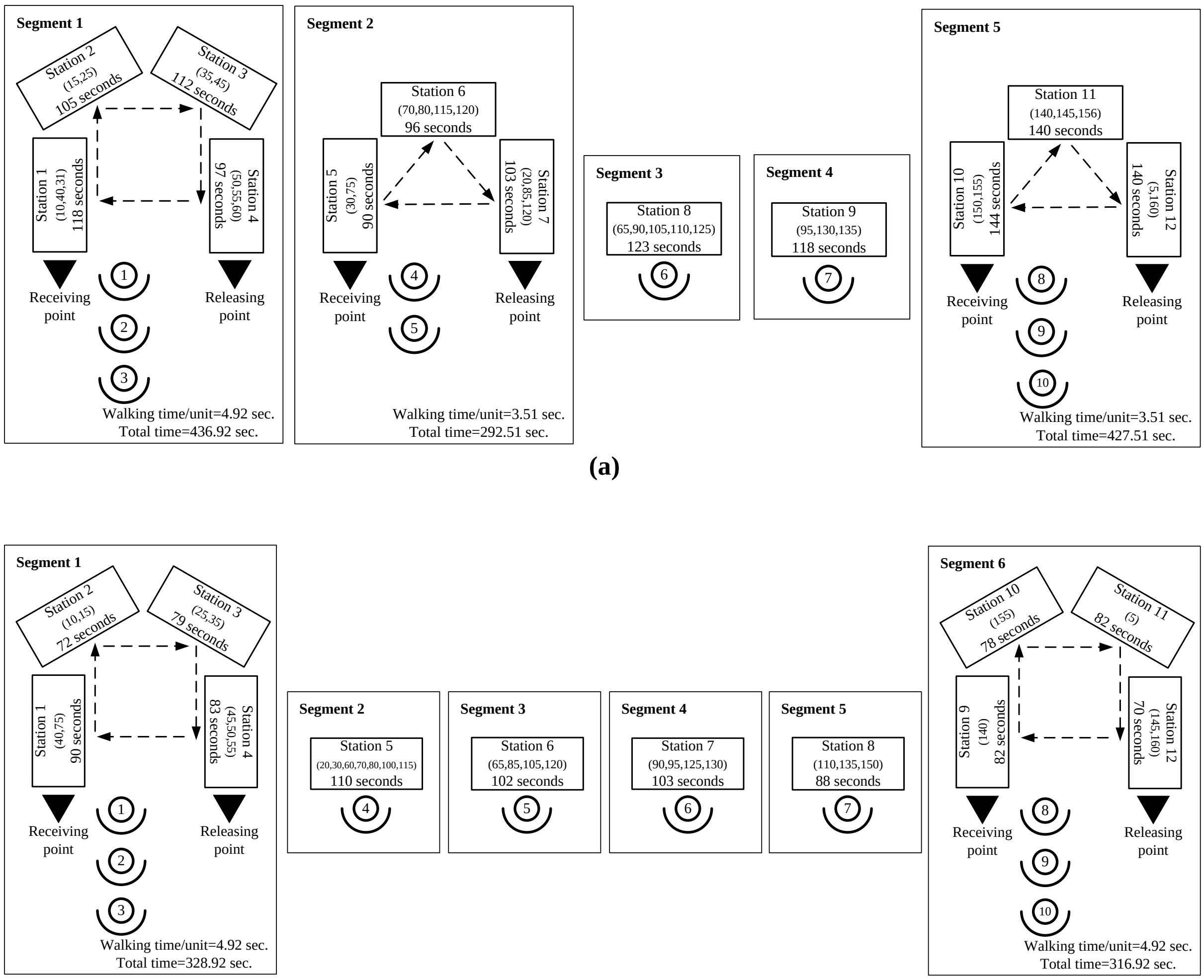
	KOP 250		**KBP 160**	
Worker	**Task(s)**	**Total Time (sec.)**	**Task(s)**	**Total Time (sec.)**
1	10, 15, 40, 25	143	10, 15, 70, 95	100
2	31, 45, 70, 95	133	25, 40	111
3	35, 50	120	30, 35, 45, 50, 55	107
4	55, 75, 30	122	60, 75, 115, 120	102
5	60, 80, 100, 115, 120	139	20, 85, 100, 105	106
6	20, 65, 85, 105, 125	138	65, 90, 110, 125	96
7	90, 110, 130	96	130, 135, 150	105
8	135, 150	131	140	102
9	155, 156	122	155	78
10	140, 145	102	5	82
11	5, 160	140	145, 160	70

When rabbit chase is considered for line design for tap-off box assembly, two segments with three workers, one segment with two workers and two one-worker segments are generated by Mathematical Programming Model 1 for KOP 250. Having same number of three-worker segments with KOP 250, KBP 160 does not require two-worker segment, but implies four one-worker segments. Then, stations are generated in each of four segments via Mathematical Programming Model 2. The proposed mathematical programming models are coded in FICO Optimization Suite using Xpress IVE 7.2 solver. The models are solved on a PC with 3.40 GHz Pentium i7 CPU and 4 GB RAM. Model 1 and Model 2 yielded CPU times of 548 and 94 (in minutes), respectively.

Layout and task assignments for segmented walking worker assembly line (SWWAL) within KOP 250 and KBP 160 production are shown in Figure 2.

A simulation study for is performed via Arena 11.0 to indicate the effects of the design alternatives within the proposed approach. Each station time which is determined by Model 2 are adapted to triangular distribution with the parameters of ($0.9\times$station time; station time; $1.1\times$station time) with the aim of providing randomness in simulation. In addition to CAL and SWWAL, overall walking worker assembly line (OWWAL), where rabbit chase is applied along the entire assembly line, is considered for simulation study.

Replication length and number of replications are 40 days (8 hours/day) and 200, respectively. Cumulative-Mean Rule is used to determine warm-up period, which is found as 1.5 hours with respect to average assembly lead time. Walking speed of workers was regarded as 1.1 m/sec. as the average walking speed suggested in Al-Zuheri (2013). Being a performance measure, assembly lead time is the time interval between the entry of the product to the first segment and its exit from the last segment. Non-value added time is denoted as the difference between assembly lead time and the total of assembly task times. Numerical results of simulation study are stated in Table 3.



(b)

Figure 2: (a) SWWAL design for KOP 250 (b) SWWAL design for KBP 160

Table 3: Results for line design alternatives for tap-off box assembly

	KOP 250			KBP 160		
	CAL	SWWAL	OWWAL	CAL	SWWAL	OWWAL
Number of workers	11	10	10	11	10	10
Average assembly lead time (sec.)	1554	1503	1532	1226	1171	1110
Non-value added time per product (%)	10.8	7.8	9.5	15.3	11.3	6.4
Average utilization for workers (%)	83.6	87.9	96	82.7	89.2	96.5
Average total walking distance (meters/unit)	-	13.13	18.26		10.82	18.26
Average total walking time (meters/unit)	-	11.94	16.60		9.84	16.60

According to Table 3, the lowest assembly lead time can be obtained by performing SWWAL (1503 seconds) for KOP 250. However, SWWAL has been outperformed by OWWAL for KBP 160 due to the fact that walking time is dominated by number of station in terms of their effects on lead time performance. The above mentioned reasons reason are valid for non-value added time ratio performance for line design alternatives. Moreover, it can be stated that OWWAL have higher utilization rates since RC ensures almost uniform utilization among lower number of workers when compared to CAL. However, the longest walking time was observed in OWWAL since workers perform assembly tasks by travelling along the stations sequentially. As a consequence, SWWAL may be regarded as the most appropriate line configuration alternative for these tap-off box assembly parameters as it yields minimum labour requirement within a reasonable performance in terms of assembly lead time and walking distance.

One-day application of each aforementioned line design alternatives has been made so as to validate simulation models. It has been observed that the simulation model represents to real-life tap-off box assembly approximately. The simulation models deviate in the intervals of [8-11]% and [4-7]% from real-life data in terms of production lead time and total walking time, respectively. Finally, tap-off box assembly system has been permanently established with respect to SWWAL configuration.

4. Conclusion

The balancing of multi model assembly lines a continuing problem for production planners. Properly balanced multi model lines can contribute to smoother production flows and more efficient use of resources. Each of the past related research has focused on the assignment of assembly tasks to stations with non-moving workers. However, relevant studies have failed to integrate rabbit chase approach with MMAL balancing problem. The main contribution of this study to the relevant literature is the consideration of walking workers in the MMAL balancing problem by means of proposing mathematical programming models and heuristic methods. Therefore, this study is thought to add value to the industry in terms of raising engineering control for the design and management of a real life assembly systems.

The effectiveness of the proposed mathematical programming models was validated by an application in a real life tap-off box assembly line. The application resulted in performance improvements for labour requirement and production lead time when compared to CAL and OWWAL. In addition, due to the computational burden of the mathematical programming approach, heuristic algorithms are developed and coded via MATLAB as a decision support system so as to ensure the appropriateness of the methodology for large-sized applications. According to the computational results on the 405 test instances, solution quality and computational convenience of the heuristic methods have been demonstrated. What is more, performance difference between heuristics has been analyzed via two-way ANOVA with respect to balancing efficiency under different problem sizes.

As a future research topic, meta-heuristic methods can be developed and compared with the proposed methodology. What is more, task times may also be considered as stochastic or fuzzy instead of deterministic for the focused problem. Another research direction would be to handle batch sequencing and balancing problems in multi model WWAL in a synchronous manner.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

The Impact of Musculoskeletal Discomfort on Tablet-assisted Education System

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Abstract

Educational ergonomics focuses on the interaction between educational performance and educational design. By improving the design or pointing out the possible problems, educational ergonomics can be utilized to have positive impacts on the student performance and thus on education process. With the advances in the technology, computers are more involved in education, with various forms. Especially tablet computers are actively used for educational purposes nowadays. Given the fact that musculoskeletal development of children and adolescents is still continuing, potential musculoskeletal problems resulting from usage of such technologies must not be disregarded. There are increasing reports of an association between increased musculoskeletal problems in children and use of such technologies. This study aims to determine the musculoskeletal risk scores of children and adolescents during tablet use in educational activities and to investigate muscular activity at the most exposed muscles. Self-reported musculoskeletal discomfort level and frequency data were collected among 406 students. Surface electromyogram was used to compare muscle activity differences of 10 students who revealed high risk scores while using tablet-assisted education systems with stands set at a 60 degrees angle. During this test, the muscle activities at neck, shoulder, upper back, lower back, wrist and forearm (wrist extensor) were assessed. The research results are critically important because making reasonable recommendations to the new generations for healthy use of tablet computers is only possible if we can understand the relationships between risk factors involved and eliminate these risks to prevent musculoskeletal discomfort.

Keywords

Musculoskeletal strain, risk score, muscle activity, education ergonomics

1. Introduction

Tablet computers have become the leading portable computing devices all over the world. In 2010, 18 million tablet computers were sold globally and this number is expected to exceed 290 million units from 2010 to 2016 (Melanson, 2011; Rotman Epps, 2012). The reasons behind the wide usage of tablet computers are their properties such as having easy to use touch screens, being small, lightweight and highly mobile, being easy to carry and use in different areas (e.g. education, healthcare, library search, and tourism), as well as in different positions (in bed, standing sitting) (Feathers and Zhang, 2012; Lin et. al., 2015; Santamarta et.al., 2015).

However, it is really of critical importance to investigate the potential negative long-term consequences of using tablet computers on children's and/or adolescents (C/A) because their musculoskeletal (MS) developments are still on-going. Their MS health should be investigated in parallel to their increasing tablet usage. It is also an interesting result that even the children themselves think that technologies such as tablet computers can have negative effects on their health (Dündar and Akçayır, 2014).

There is no earlier study focusing on tablet computer assisted education, which especially focused on the usage of C/A and involved C/A with regard to education content. The objective of this study is to investigate the muscle activities at the most exposed muscles of upper body of the students during a class activity using tablet computers, according to the levels of risk scores (discomfort score) assessed using Student Specific Cornel Musculoskeletal Discomfort Questionnaire (SS-CMDQ).

There is an obvious gap in the literature focusing on tablet computer use of C/A involved in a tablet-assisted education programme. Thus, this research tries to fill this gap by studying the muscles activity of C/A in a tablet-assisted education programme. Therefore, the aims of our research are to determine the MS discomfort risk scores of C/A during tablet computer use in tablet assisted education programme, and to investigate muscle activity at the most exposed upper body regions.

2. Literature Review

Several studies in the literature focused on C/A's use of tablet computer have investigated MS discomfort (Alamargot and Morin, 2015; Aly et.al., 2015; Portnoy et. al., 2015; Sommerich et. al., 2007; Straker et.al., 2008; ;Straker et.al., 2015), and high risk of MS disorders were implied especially by neck discomfort and high frequency of MS discomfort.

Being one of the first studies to investigate ergonomic aspects of tablet computer in relation to student use, Sommerich et. al. (2007) conducted a study to collect data (experiences, attitudes, physical discomfort) from students using two-part questionnaire and a computer-use monitoring software. Their results showed that student's experiences are not usually problematic, student's attitudes are commonly positive using a tablet computer, however students experienced discomfort associated with tablet computer in several body parts (e.g. eyes, neck, head, and right hand/wrist, upper and lower back.)

The first study which investigate the MS system of young children was constructed by Straker et. al. (2008). The researchers compared the posture and muscle activities of young children during tablet computer, desktop, and paper technology in school. Their results showed that tablet computer use was associated with greater neck and trunk flexion, greater flexion and elevation in shoulders and greater muscle activity around neck when compared to desktop computer use.

Alamargot and Morin (2015) compared the graphomotor activities of students using a plastic-tipped pen to write tablet computer and ballpoint pen to write on a paper. The study suggests that handwriting on a tablet using a plastic pen leads to disturbance in segment trajectory calculation for younger participants and in the execution of motor programs for older participants.

Straker et. al. (2015) conducted a study on the differences between muscular activities of children while using tablet computers and while doing other children activities (e.g. playing with toys and watching TV). The arm movement, upper limb and trunk posture, as well as neck/shoulder muscle activity of children were investigated during three activities (i.e. free play environment, playing with tablet computer, watching TV). Their results indicated that using table computer increased the risk of MS discomfort among children. In addition, tablet computer use resulted in less movement, muscle activity and bad spinal posture compared to other children activities.

Aly et. al. (2015) conducted sEMG study to determine muscle activities (i.e. wrist and neck) in children and to study the effects of tablet gaming on pain threshold in shoulder region, during tablet gaming, while the play duration was one of the critical factors. Their results supported the hypothesis of tablet playing is associated with increased neck and wrist muscle activities in addition to decreasing the pain threshold in the shoulder region.

Portnoy et. al. (2015) examined the performance in tracing tasks and in copying figures among preschool children using a tablet computer in two different postures (i.e. sitting a desk and standing in front of wall). Their results showed that the muscle activity while drawing in sitting or standing position was not significantly different among a group of 35 children. Also, they showed that there were no difference between the performance level of task while sitting posture and standing posture. However, different muscle activities were occurred.

Nowadays, especially tablet computers are actively used for educational purposes. Many countries, such as USA, Uruguay, Argentina, and Turkey, have invested in the educational technology projects in schools (Trucano, 2013). An example to these projects is "Fatih Project", which is supported by the Ministry of National Education in Turkey. In primary and secondary schools, government provided a tablet computer to students to expand computer-integrated education throughout all stages of education system of the state where, a total of 620,000 smart boards (for classrooms), and 17 million tablet computers (for students), 1 (one) million tablet computers (for teachers and administrators) were utilized (Şimşek and Doğru, 2014). Moreover, using mobile technologies in education positively affects student's attitude, makes education enjoyable, eliminates the need to carry books, enable the students to take dynamic notes using digital pen, and makes the use of game prototypes possible for math education (Audi and Gouia-Zaarad, 2013; Dündar and Akçayır, 2014; Enriquez, 2010; Fister and McCarthy, 2008; Kucirkova et. al., 2014; Lim, 2011; Oleson et. al., 2011).

3. Methods

This research is designed to determine the MS discomfort risk scores of C/A to study muscular activity of their upper bodies' during simulated in-class activities. The first phase of the study was designed as a two-part questionnaire, where the first part collects information on the respondent's attitude and habits related to desktop/laptop/tablet computer use. The second part of the questionnaire consists of the Student Specific Cornell Musculoskeletal Discomfort Questionnaire (SS-CMDQ) which was developed by Erdinç and Ekşioğlu (2009a & 2009b). The SS-CMDQ is a variation of Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), which evaluates pain or discomfort frequency for the past week and checks if academic activities of students were interrupted by any discomfort experienced. CMDQ (CUergo, 1999) is a questionnaire that was constructed to find out details about subjects who are under high risk of experiencing MS problems. Both Turkish and English versions of SS-CMDQ was utilized in the study (Erdinç and Ekşioğlu, 2009a & 2009b).

The research has been granted an approval by the Ethics Committee of the Eastern Mediterranean University. The approval was issued on 17/02/2015 with decision number 2014/04-01. In addition, the General Secondary Education Department of Ministry of Education approved the research to be performed after an investigation of the documentation of the planned research activities by the Board of Education and Discipline under the General Secondary Education Department of the Ministry. Parental consents were also taken for all the students who participated in the study.

3.1 Questionnaire – The First Phase

The first part of the questionnaire was developed based on detailed literature survey, particularly including the Dutch Musculoskeletal Questionnaire (DMQ) by Hildebrandt et. al. (2001). In addition to demographic data, the first part collected information on reasons, location, duration and history of desktop/laptop/tablet computer use of the participants; habits and attitudes of respondents towards their desktop/laptop/tablet use, and finally lifestyles of the respondents.

The second part of the questionnaire was the SS-CMDQ where both Turkish and English versions were utilized as there were students from different nationalities in the student sample. Then the students with high discomfort scores were invited to form the test group of the second phase, where their muscular activities were recorded by surface Electromyogram (sEMG).

Both the first part and the second part (i.e. SS-CMDQ) of the questionnaire were applied to students in both private and public secondary high schools located in northern Cyprus. The second part of the questionnaire was utilized to investigate any significant relationship between the frequency and severity of MS discomfort and the desktop/laptop/tablet computer use of students, and the interference of the experienced discomfort with the academic activities. SS-CMDQ was administered with the help of a body map diagram to determine discomfort scores (risk scores) of the respondent students.

SS-CMDQ consists of three parts related to the frequency of occurrence, the level of MS discomfort experienced, and the effect of experienced MS discomfort to the performance of academic activities of the respondents. The students who experienced of ache/pain/discomfort during the last 7 days provided the problematic body parts with the help of the SS-CMDQ's body map diagram. The answers to the questions related with severity of the problem or interference with the school activities were required only from the respondents with one or more experience(s) of discomfort within the last 7 days.

The frequency of discomfort scales ranged from none to several times a day (0-10), severity of MS discomfort scale ranged from slightly uncomfortable to very uncomfortable (1-3), and the effect of experienced MS discomfort (interference) scale ranged from not at all to substantially interfered (1-3). These scales are used in calculation of discomfort scores for the students, who reported to have ache, pain, or discomfort in one or more body parts.

In order to replace the missing values and in calculation of each three type of score (i.e. frequency, severity and interference scores of CMDQ) the weights proposed by Hedge et al. (1999) were used. The only assumption for missing values cases was that the null frequency scores were replaced by zeros; therefore the discomfort/risk score were at least the value of the frequency score.

3.2 Surface Electromyogram– The Second Phase

Respondents with high discomfort scores from SS-CMDQ formed the high risk group of experiencing MS discomfort. Therefore, the high discomfort group was invited to participate in the surface electromyogram analysis. The aim of this phase was to test the research hypothesis of mean MS strain of each individual of the test group - in different body regions - does not differ in time. The measurements were recorded as amplitudes (in microvolts). The mean MS strain of each muscle group of each respondent was compared to identify whether underlying patterns (statistical distributions) of the mean MS strains recorded in time were the same or not.

3.3 Participants

3.3.1 Participants of the study

According to the Statistical Yearbook of 2014 (the Ministry of Education of Turkish Republic of Northern Cyprus, Department of Common Services for Education, 2014) in Academic Year 2013-2014 the number of governmental and private secondary and high school students were 18,249 in northern Cyprus. As a result, using Yamane's formula (95% confidence level and 5% sampling error) for such a population (18,249 students) 391 subjects were accepted to be sufficient for data analysis. In the research process 500 questionnaires were distributed through school managements and 406 of the distributed questionnaires were filled correctly.

3.3.2 Participants of sEMG study

The SS-CMDQ discomfort/risk score of each student was calculated by first assigning weights (ratings) to the scale for frequency discomfort and then multiplying weighted frequency, by discomfort and interference scores. In total 30 students having discomfort scores above 90 formed the high discomfort group. Amongst the high discomfort group, 10 respondents agreed to participate in sEMG study and formed the test group.

Moreover, among those students who revealed low discomfort scores, 4 of them were also invited to the control group with the consent of their parents. Thus, totally 14 students participated in the sEMG experiment.

14 students (8 male and 6 female) were further participated in the muscular analysis study with written parental consent forms. 10 of these students (6 male and 4 female) were invited to form the test group who were selected from the high discomfort score list of the SS-CMDQ results. The control group participants (2 male and 2 female) were also invited from the zero discomfort/risk score list. The age of the participants who consented to attend the sEMG assessment sessions, ranged between 12 and 17. None of the participants had a history of MS disorder. All attending students were restricted by right-handed students.

3.4 Muscle Assessments

A two-channel MyoTrac Infinity sEMG device with raw sensors was utilized to collect surface myoelectric activity signals. The muscles to be assessed were also determined using the results of the SS-CMDQ. 6 body regions of the upper body exhibited high risk/discomfort scores compared to other upper body regions. Therefore, they have become the pivoted muscle groups of the study and in sEMG assessment these muscle groups were registered to record their mean MS strain.

Raw sEMG signals were collected via the two-channel sEMG device, therefore for each subject we had to pause the recordings and give two 5-minute brakes to the class activity for changing the places of electrodes. Halaki and Ginn (2012) have categorized the studies of EMG in terms of the need for normalization. They summarized that for the assessments of EMG on the same subject on the same day, without changing the configuration and environment, raw data can be used without normalization. In other words, if the study is not comparing different subjects' muscles, and is only working with the amplitude of the signals, normalization is not required. Furthermore, "normalization exercises on children" is a topic that has not been clear yet in literature. Therefore, raw data had been used in this study. The students, who were called for sEMG measurements in simulated class environment, were not informed whether they are in the test group or control group.

The sEMG data was collected from C4 cervical paraspinals (CP), upper trapezius (UT), thoracic paraspinals (upper back), lumbar paraspinals (lower back), wrist-extensor (forearm), and wrist muscle groups. All measurements were collected from right-hand side (our sample included only right-handed students). In addition, all sEMG measurements sessions were done while the students were using desk stands for tablets and although both hands of the subjects were free most of the time the right hand side of the participants were active because of being right-handed. Here, it is important to mention that participants used the tablets with desk stands at 60 degrees (Throughout the experiments same type of tablet and same tablet stands were used, the simplest form of tablet desks stands, which is also used as the case has two options: 45 and 60 degrees options. Here, 60 degrees desk stand represents the stand that makes a 60-degree angle with the table surface resulting in a backward tilt of the tablet for all sEMG subjects.

Prior to running and recording the sessions with sEMG, a trial run was performed in order to check if the recordings are sensitive to motions. Two different types (strip shaped and triode electrode) of disposable electrodes were used for ease of positioning the electrode correctly during data collection through sEMG.

3.4.1 During and before the sEMG measurements

Socrative software that is made for tablet-assisted education was used as an interface between the in-class activities. Two in-class activities (one in English and one in Turkish) were offered to the students because of language restrictions aroused by involving both private and public schools. The students worked on these activities throughout the sEMG recordings. The students were asked to act as if they are in a real classroom and they were informed that they were not having a test or exam, and they can ask questions if there are questions that are not clear for them.

No time limit mass imposed on the students for performing these activities during sEMG recordings. Thus, there are different numbers of measurements even for each muscle group of the same participant. However, the least number of recordings were considered as a benchmark for both statistical tests and for regular comparisons with graphics.

3.4.2 Mean Muscle Activity

Mean values of the raw microvolt data are updated every 5 seconds in Biograph-Infinity Software, which is the interface of our 2-channel sEMG device. Mean values were computed from the collected data every 20 seconds.

4. Results

406 out of 500 questionnaires were collected from the respondent students, with a response rate of 81.2%. Although, there was no effort to balance gender split among the respondents, the proportion of the male and female participants were 50.7% and 49.3% respectively. Student demographics of the 406 respondents can be found in Table 1.

Table 1. Student demographics (*n*=406)

Variables	Range	Sample Mean	Std. Dev.
Age	11-20 years old	14.06	2.19
Height	1.25 m-1.90 m	1.62	0.11
Weight	28-96 kg	55.07 kg	13.83

Among the tablet user respondents, 69% of the respondents who reported high discomfort in SS-CMDQ, were grouped as prolonged tablet users in the first part of the questionnaire. In addition, 67% of high-risk group respondents are tablet users experiencing high discomfort in at lease one of the six body parts under study. Also, 76.6% of the questionnaire respondents reported at least one type of discomfort during the past two weeks, considering the fact that 67.9% of respondents were tablet users.

Table 2 shows that the respondents experienced MS discomfort mostly at the neck (42.36%), upper back (41.12%), lower back (38.67%), and shoulder (22.41%).

Table 2. Percentage of experienced of MS discomfort (*n*=406)

Body Region	Yes	No
Neck	42.36%	57.64%
Shoulder (right)	22.41%	77.59%
Shoulder (left)	15.52%	84.48%
Upper back	41.13%	58.87%
Upper arm (right)	9.61%	90.39%
Upper Arm (left)	9.61%	90.39%
Lower back	38.67%	61.33%
Forearm (right)	10.59%	89.41%
Forearm (left)	8.62%	91.38%
Wrist (right)	19.46%	80.54%
Wrist (left)	12.07%	87.93%
Hand/fingers (right)	12.81%	87.19%
Hand/fingers (left)	11.58%	88.42%
Hip/Buttocks	14.29%	85.71%
Thigh (right)	16.26%	83.74%
Thigh (left)	15.27%	84.73%
Knee (right)	15.27%	84.73%
Knee (left)	13.79%	86.21%
Lower leg (right)	15.02%	84.98%
Lower leg (left)	13.55%	86.45%

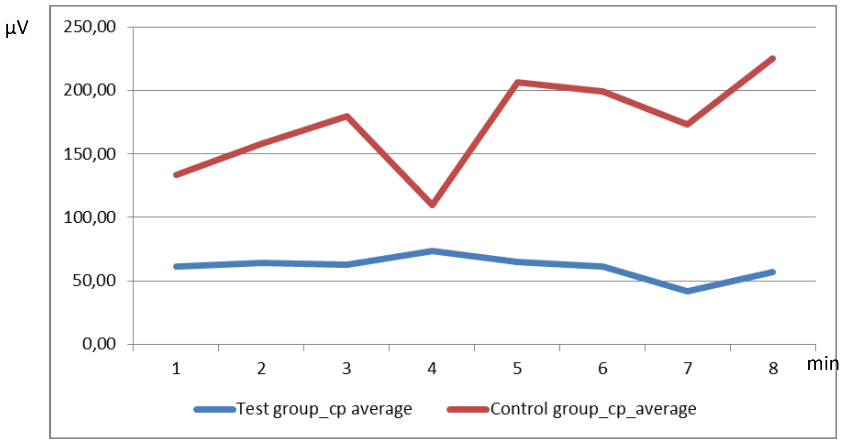

Figure 1: Mean MS activity at cervical paraspinals (*n*=14)

Figure 1 shows that mean MS activity at CP of the control group was observed to be higher than that of the test group. Beyond that, it was observed that the mean MS activity at CP of the control group was observed to have an increasing trend in time, whereas that of the test group was almost stable.

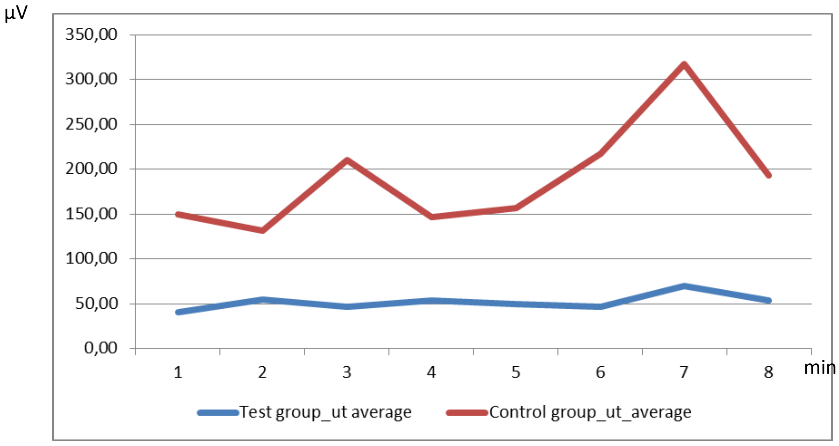

Figure 2: Mean MS activity at upper trapezius (*n*=14)

Similarly, Figure 2 illustrates that the mean MS activity at UT of the control group was higher than that of the test group. Nonetheless, the mean MS activity at UT of the control group was again showed an increasing trend, whereas that of the test group was constant throughout the measurement.

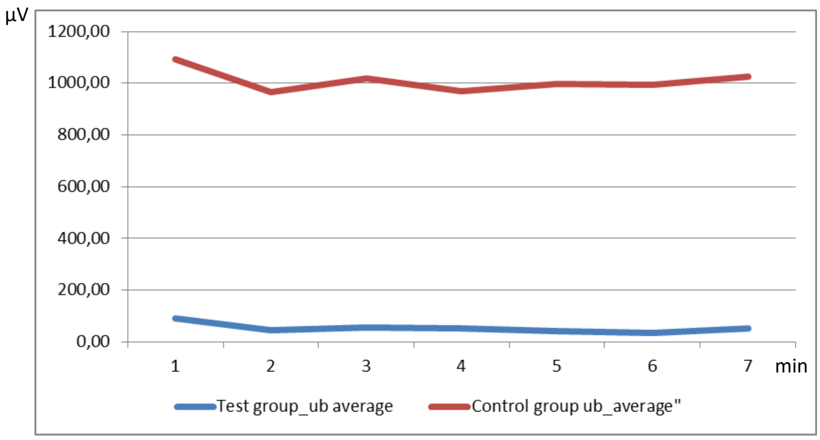

Figure 3: Mean MS activity at upper back (*n*=14)

Figure 3 shows that even though both groups were observed to have a stable mean MS activity throughout the time; the control group was significantly higher than that of the test group at the upper back.

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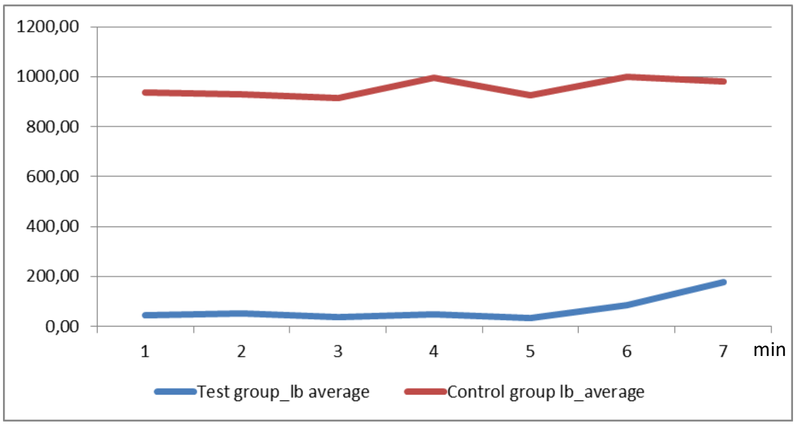

Figure 4: mean musculoskeletal activity at lower back (*n*=14)

There was a significant difference between the mean MS activity of the control and test groups at the lower back (Figure 4). Both groups showed a linear constant behaviour throughout the measurement. The control group experienced very high levels of muscle activities, while the test group muscle activities were minimal.

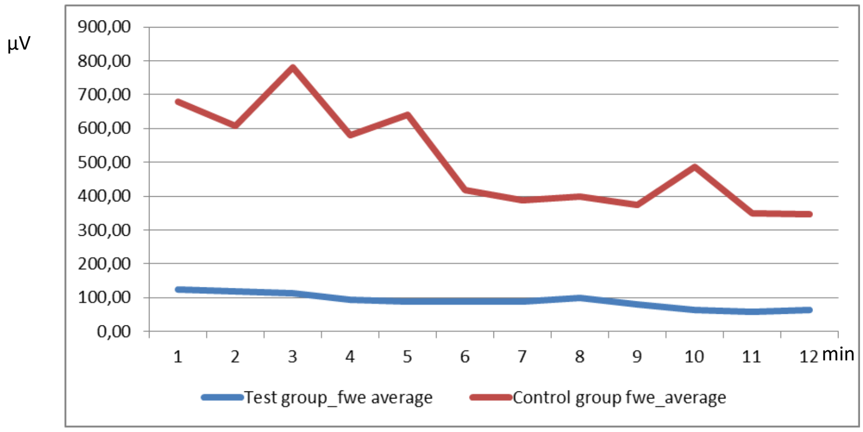

Figure 5: mean MS activity at forearm/wrist-extensor (*n*=14)

Figure 5 shows that again the control group experienced significantly higher mean MS activity than the test group at the forearm/wrist-extensor. It was observed that while the mean MS activity of the control group had a linearly decreasing trend, the test group experienced constant level of MS activity in time.

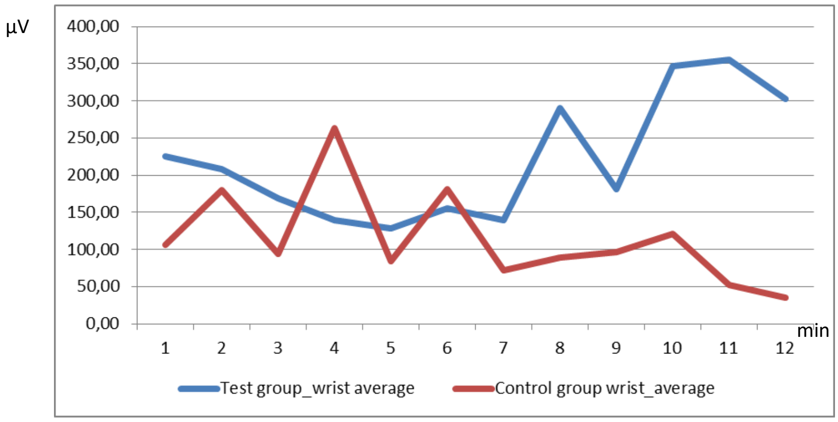

Figure 6: mean MS activity at wrist (*n*=14)

Amongst all muscle groups recorded, solely the mean MS activity at the wrist of the test group respondents was higher than that of the control group. Moreover, the mean MS activity showed a decreasing trend until the half of the measurement, and then it was observed to have a significant increase. On the other hand, the mean MS activity of the control group was observed to have a linearly decreasing trend during the test.

A one-way analysis of variance (ANOVA) has been performed to test whether there is a significant difference in variance for muscular activity of each muscle group of the participant (over the period of time he/she worked on the class activity). This test also identifies the most exposed/strained muscle group(s) of the participants. There were differences among the duration of the measurements of muscle groups, because the student profiles and capabilities of our simulated class environment are different than in a regular class environment.

ANOVA results of the test group (Table 3) imply that there is a significant statistical difference for six muscle groups for each participant. These results provide that the research hypothesis is failed, thus the mean MS strain of the tested six muscle groups are significantly different.

Table 3: ANOVA results of test group respondents (*n*=10)

Participant	F	P-Value	F critical
1	48,29	0,00	2,30
2	9,45	0,00	2,32
3	19,16	0,00	2,47
4	3,04	0,01	2,33
5	25,33	0,00	2,34
6	41,32	0,00	2,30
7	7,43	0,00	2,33
8	6,95	0,00	2,31
9	324,88	0,00	2,43
10	22,07	0,00	2,38

However, the control group revealed different results (Table 4). ANOVA showed that, for two (participants 11 and 12) out four control group participants, there was no significant difference between their 6 muscle groups (alpha=0.05).

Table 4: ANOVA results of control group respondents (*n*=4)

Participant	F	P-Value	F critical
11	0,70	0,62	2,33
12	1,48	0,20	2,34
13	940,63	0,00	2,28
14	13,25	0,00	2,3

5. Discussion

To the best of our knowledge, this is the first study that integrates tablet-assisted class/education environment, students, and students' MS health. The statistical results of ANOVA would be more powerful if we could recruit more students for the control group.

Unlike the test group, the students were the resisting party in recruiting control group participants, not the parents. One of the most probable reasons for this resistance is because they are not used to be involved in activities with tablet computers. For stronger results, that will support the research, future studies must recruit more participants especially for the control group. In such a case, the difference between the participants recruited from high-risk group and low risk group would be more obvious.

If tablet-assisted education would increase the risk of MS discomfort, then the researchers should suggest some prevention methods. For example, give a 5 minutes break every 30 minutes computer use; or a simple set of 5-6 minute exercises may be offered by physiotherapy doctors that will be repeated at least two times a day to balance the muscle activities again aiming a relief in any discomfort being experienced (CEO Sydney, 2015; Straker et.al., 2008; Straker et. al., 2010). Of course, the most important of all is the right educational furniture selection for an acceptable posture during the course of tablet usage in class.

The need for ergonomic principles for C/A are obvious, as most of the respondents reported that they have experienced discomfort ranging from slightly uncomfortable to very uncomfortable (nearly 80%) in the past two weeks. Thus, ergonomic principles can be taught by the teachers of tablet-integrated or tablet assisted programs to help children adopt good postures to decrease or eliminate the discomfort they experience.

6. Conclusion

There is a gap in the literature focusing on educational tablet computer use of C/A or on C/A in a tablet-assisted education programme. As a result, this research tries to fill this gap by studying the muscles activity of C/A in tablet-assisted education programme.

Results of the study imply that prolonged tablet usage among education increase the risk of students to experience MS discomfort. It is really notable that nearly 70% of respondents, who both use tablet computers and have high-risk score of experiencing MS disorders, are also among the long-hour tablet users list.

MS discomfort was experienced mostly at the neck (42.36%), upper back (41.12%), lower back (38.67%), and shoulder (22.41%) regions. In addition, around 67% of high-risk group respondents are tablet users experiencing high discomfort in at lease one of the six body parts under study. It is even possible that these percentages are underestimated because some children may not be really aware of the discomfort they experience after long exposure to mobile technologies.

The sEMG measurements provided that the mean MS activity at the cervical paraspinals, upper trapezius, upper back, lower back, and forearm/wrist-extensor was significantly higher for the control group respondents during tablet use. However, only at the wrist region, the test group respondents experienced higher MS activity throughout the test.

ANOVA results showed that the mean MS strain - in different body regions - does significantly differ in time for all tests group respondents during tablet use. However, they hypothesis was failed to be rejected amongst some of the control group respondents.

Thus, it can be concluded that this research indicates a significant relationship between tablet use and high MS discomfort score.

Acknowledgements

We hereby thank to all school managements, parents and especially the students who made it possible for us to gather such valuable information both for this study and for our future studies.

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Multi-factor Frameworks and Models for Innovation Risk Management

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Abstract

This paper forms the basis for a work-in-progress-academic research that proposes that innovation-risk management should be treated as its own body of knowledge, with its own methodologies and templates, and leveraged as a mechanism for increasing competitive advantage and guarding core competency. Because this is not yet the case, the paper proposes the development of templates and methodologies useful for advantageously leveraging innovation-risk management in a competitive environment.

Innovation has a symbiotic relationship with risk management. The paper highlights how innovation management can benefit from risk management and promotes the building of new frameworks for gathering, measuring and disclosing innovation-risk information. The paper examines the current state of innovation management, notes the advantages and especially the disadvantages that proposed frameworks must address within a new hybrid construct dubbed innovation-risk management. The new theoretical model is aimed at addressing some of the shortcomings of not having a holistic risk component built into the innovation management process(es). Thus proposing an innovation risk management model.

Risk management is a dynamic process especially because of the qualitative component driven by expert judgement and retrospection. Innovation risk management is only made complex because of the unpredictability of innovation activities but it can otherwise be a straight forward investigative theory. This paper therefore seeks to establish innovation risk management as a workable and effective process presenting a holistic and diversified set of frameworks and models that can adequately support innovation process activities.

The opinions of practitioners are important in establishing this body of work. This effort of producing innovation risk management frameworks will therefore be validated via the application of the frameworks produced against one hundred and fifty (150) business initiatives within the legal and compliance, trade and other business activities in the banking sector. Some of these initiatives are new but most are already in use. Findings gathered from 38 of the 150 initiatives examined, show how best to improve and maximise on the framework's potential application. This paper will suggest when and where throughout an innovation process it is best to use these models. The frameworks are intended to be used by innovation risk consultants in guiding innovation development. The validated frameworks are bespoke risk models and seek to separate themselves from any other generic or specific framework by having specific relevance to innovation. The goals of a robust innovation risk model are examined in context of these business initiatives in order to determine their viability and collective effectiveness as a proposed innovation risk framework.

This paper forms a part of an ongoing PhD effort by the author, titled under the same name: "Multi-factor Frameworks and Models for Innovation Risk Management" and some of the current findings are as follows: Innovation practitioners do not have specific tools and methodologies to apply to an innovation process that are not only dynamic but are impacted by various other factors. When the key factors can be identified then the frameworks applied can be somewhat standardized giving the practitioner better leverage for success in innovation.

Keywords

Innovation Management, Risk Management, Innovation Risk Management.

1. Introduction

A previous position paper "Identifying the Need for Innovation Risk Management" (2014) highlighted that innovation is risky and failure to innovate is costly. That paper examined the literature and best practices in innovation and risk management and proposed a basis for an innovation risk management framework. The need to reduce costs and limit the failures in innovation motivated the development of a composite theory for innovation risk management strategy. The paper had highlighted the fact that there are five types of risks considered in association with innovation: Technological risks, Organizational and Societal Risks Market Risks Financial Risks and finally Turbulence Risks.

The risk management theory that was considered in the aforementioned writing originated from project risk management (Mulcahy, 2010), (PMI-RMP, 2011), (PMI, PMBOK, 2012) in tandem with some of the managerial insights that connect this current research to the real world and is presented in the context of technology applications used to enhance business processes. The paper gets input from technology innovation assets used in banking and finance to carry out various business processes and/or functional activities.

Part of the hypothesis presented within this paper is that innovation risk is owned and subjectively quantified by risk experts. The system of ideas applied to this supposition includes regulatory, fiscal, legal, and financial reward driven. Not applying an effective innovation risk management strategy can impact profit and reduce management credibility, both of which have profound negative impact on the company's innovation and performance (Mollick, 2013). The aim therefore is to produce a theory intended to explain and guide risk stakeholders towards responsibly choosing risk paths based on a policy driven risk appetite. We do not end up with any complex models as innovation despite the dynamics in innovation, as risk management has very heuristic and uncomplicated principles.

These principles include the quantification of the innovation risk with categorization and classification applied on a business (or impact) perspective, technical and also compliance level. The value of this research can be justified through real business problem application regulatory approved (audited and validated) and recertified over time by a multiplicity of stake holders as innovation and business needs change. The Models are executed in multi-parts by stakeholders who are versed in each of the principle areas of focus mentioned, for example business specific, technical, and general/holistic compliance.

Previously proposed was the joining of the two theories of Innovation Management and Risk Management to provide a composite theory for Innovation Risk Management (Boothe, van Kasteren, & Terzidis, 2014). Innovation is applied to products, services and processes Schumpeter (Ina, 2004) this paper focuses on services in banking and is compatible with the dynamics of change that regulatory, fiscal, and legal brings. The frameworks proposed intends to bring three advantages: the ability to identify innovation risks early and causing stakeholder engagement around all perspectives of the risk faced (as stated above in the specific context of business, technical and holistic compliance). Second, planning responses such as contingencies as guided by risk appetite and sanctioned by regulation and laws. Third, monitoring and control which also builds up knowledge gained in previous innovation processes and activities. The application of risk management to innovation is relevant and have been proven in other areas (Morris, 2008). This paper, partly through the efforts of application to multiple innovation cases, intends to proof an own set of tools adopted from other mature areas and standardize the tools specifically for innovation management.

This reading will now be structured as follows. In Section 2, the paper will present the merits of having innovation-risk management as a unique body of knowledge, with its own methodologies and templates and in Section 3, highlight the innovation and risk management and the symbiotic relationship that they share. Presenting also a proposal for building new frameworks for gathering, measuring and disclosing innovation-risk information. The fourth, Section 4, will examine the current state of innovation management, noting its advantages and disadvantages show how a new construct which includes risk management addresses some of the shortcomings of not having a holistic risk component built into the innovation management process(es).

2. Merits of Innovation Risk Management

As echoed before, failing at innovation is costly (Christensen & Raynor, 2003). Innovation can be in the form of tangible and intangible products both the extremely useful to the bizarre - as widely recognized through the ages from the Wheel to the 'Diamond App'. Innovation can also be in the form of services as opposed to products, where the 'how-to' of applying risk management is not as clear. A 2014 paper highlighting risk and strategies in Brazilian innovation supports the notion that changes in regulatory environment, the pressure of society, and the [risk and] opportunities to meet the demands of current customers […] (Olivia, et al., 2014) has caused innovators to dedicate effort not only on the innovation being offered but also towards logistics and delivery of innovation. We see here that innovation does not end with the creation of a product but also continues through to the (repeatable) delivery to the customer. Innovation management in this context requires a very broad and holistic approach offered by having a specific focus on the unique notion of innovation risk management.

"It seems reasonable, then, to suppose that the more factors your model incorporates, the better your assessment will be of the risks you incur in deciding whether and how to adopt a particular innovation. That explains to a great extent the popularity of mathematical modeling, especially with respect to technological and financial innovations" (Merton, Innovation Risk: How to Make Smarter Decisions, 2013).

Risk management can play a positive role at every stage of the innovation management process. The stages of the risk management process in tandem with methods of innovation selection, cost of innovation, and organizational management in relation to the application of innovation are but a few of the elements that a risk based approach to innovation management would improve (EU*Research, 2010).

Over the development life cycle of this theoretical work-in-progress, writings specific to innovation risk management have become more visible since 2012. It would make some sense to classify the various innovation problems that predominantly arise and prepare risk or opportunity driven solutions to them (Guo, 2012) but the assumptions made in such proposal do not encapsulate all innovation problems faced and across the innovation spectrum the cost of incorrect classification is never the same proving deadly for small firms and time consuming and cost generating for medium to large firms (Thun & Hoenig, 2011). Some experts contend that responsible innovation risk management would necessitates a cautious approach to each innovation effort. Notably, while large global companies have complex controls and often silo type innovation activities that are shielded from other business activities or alternatively the option of a stage-gated approach to reduce uncertainty, by any means nonetheless startups can hardly afford to court the risk of failure. The Section on State of the Art in Innovation Theory will elaborate on the pitfall of incorrect classification showing that there are weaknesses in measures applied to innovation without considering risk, ultimately bringing failure (Stulz, 2008).

The merit therefore in having a unique innovation risk management theory is in avoiding costly failure using applicable innovation risk decision rules. Another merit is in minimizing the probability of error in innovation feature selection (also leading to failure). These features are important for understanding the type and potential of risks and opportunities in innovation aided by the identification and qualification of those same potential risks and opportunities. The right framework is selected through this know-how and applied in the context of the pursued innovation. Currently, research focused on innovations are about methods and modes that promote the development of independent innovation methods but they seldom focus on risks (Alon & Hooper, 2012).

A third merit is that innovation risk decision-making through the proposed framework approach seeks to work with the most complete information possible, although no process or subject matter expert can foresee all the consequences of an innovation, no matter how obvious they may seem in hindsight (Merton, Harvard Business Review, 2013) we pursue a best effort approach with the application of the proposed multi-feature approach. A feature is an observable variable, henceforth factor, selected from an innovation space within which observations can be distinctly made.

Industry consultants on risk management have sought to fuse innovation with agile, sophisticated approaches from risk management aiming to create a powerful and value creating results risk management has further merit of being flexible and expert opinion driven. There are other merits that can be identified but these will be further elaborated upon within this paper. The cost of innovation is well documented (Horrobin, 2000), (DiMasi, W., Henry, & Louis, 1991). Are decision rules important for guiding the innovation selection processes? How often are the correct and relevant factors selected in your innovation for innovation success? How complete is the information that is gathered for innovation activities? And can expert opinion always be relied on in carrying out innovation activities? These were amongst the varied questions posed to risk assurance experts to which this research had access.

2.1 Quantifying the merits

Between October 2015 and April 2016 practitioners involved in risk assurance and some involved in innovation activities have responded to these questions yielding the following results – percentages reflect those responding YES as opposed to NO:

M1[a]	**M2[a]**	**M3[a]**	**M4[a]**
Decision rules are important for guiding the innovation selection processes	The correct and relevant factors are always selected in innovation development	Information is often sufficient or complete for pursuing innovation activities	Expert opinion can always be relied on in carrying out innovation activities
99%	47%	87%	72%

M1[b]	**M2[b]**	**M3[b]**	**M4[b]**
Decision rules are consistently applied in every innovation selection	Is a synergy or correlation to core competency relevant to factor selection?	External sources of information are important in the innovation process	The enterprise has sufficient experts internally
42%	98%	100%	52%

M1[c]	**M2[c]**	**M3[c]**	**M4[c]**
All stakeholders are involved in creating decision rules	Is there high confidence in factor selection as a method for innovation success?	The cost of information is a significant part of gaining an advantage in innovation	Tools and frameworks would be important and helpful
15%	47%	64%	94%

M1[d]	**M2[d]**	**M3[d]**	**M4[d]**
Decision rules are reusable across innovation initiatives	Are external factors more potent than internal factors when pursuing innovation?	The cost of misinformation has been prohibitive to continued innovation activities	Quantitative methods are applied in innovation selection
82%	50%	63%	73%

Number of respondents = 38

The respondents come from global hubs London, Frankfurt, Singapore, New York and Prune and are predominantly subject matter experts for financial risk assurance. Carried out during global risk management calls, the feedback supports the merits of having an innovation risk framework in the following way:

It is suggested that the proposed theory of a Multi-Factor Framework can improve the state of the art in innovation management by focusing on the use of relevant decision rules. Decision rules may be logic based, heuristic or, weighted. Given the lower rate of success to that of failure in innovation, decision rules uniquely applied in innovation idea selection has an opportunity to improve innovation success. Where it is not cost prohibitive to do so, a maximum cross-section of stakeholders and the innovation risk-bearers should impact the decision rules used. The rules being reusable should continue to be a feature in the proposed theory.

The Frameworks should improve the selection of innovation success factors. This task requires more research to determine the best practices in achieving the goal. While the feedback suggests that correlation to core competency is important, it is counter intuitive to the nature of and serendipity of innovation. There are sufficient examples of disruptive innovation that proves this to be a true. Nonetheless, there is less than majority confidence in factor selection this reiterating the complexity of innovation management.

Practitioners believe they often have sufficient information for pursuing innovation activities, how then do they account for often failed innovation? They welcome external sources of information as many cannot afford the cost of research associated … This cost of information is a significant part of gaining an advantage in innovation and conversely the cost of misinformation has been prohibitive to continued innovation activities.

The feedback further indicates by majority opinion that expert opinion can always be relied on in carrying out innovation activities therefore the frameworks and templates must be endorsed by both the enterprise internal and external experts. Tools and frameworks would be important and helpful and must include a means of incorporating quantitative methods.

3. Innovation and Risk Management

Innovation management can benefit more from the risk-innovation relationship. Innovation brings higher margins increased product diversification and differentiation, satisfied and expanded customer base, market security, and other competitive advantages but remains an abnormality in doing business (Christensen & Raynor, 2003). Risk management generally is a more mature practice and therefore innovation management can and will benefit from the more established applications of risk management. Practitioners of risk management may not all be familiar with innovation management but those exposed to both theories agree that the symbiotic association is in the favor of innovation. Innovation management can be combined with risk management as a new value adding composite process and easily be adapted to old and new management processes. Risk management provides better assurances for product acceptance, better ROI, better resource allocation options, new and effective innovation risk responses, alternatives to critical dependences that generally threaten innovation, capacity building, and adds transparency via benchmarking of the overall process. On any level and from any dimension applicable there are benefits for the field of innovation when risk management is applied. The importance of understanding the maturity level of available theories leads us to understanding how to apply them and what support is available in making them workable and effectively successful. Lessons learned and knowledge banks enrich tools that are commonly used to support the innovation process but this is more likely true for mature management practices and based on retrospective analytics made popular from the realm of finance. Innovation knowledge should include information on failures and challenges.

Frameworks should include adoption strategies. Innovation risk can largely be measured from the decisions made by people who adopt those innovations (Merton, Harvard Business Review, 2013). The frameworks should encompass learning garnered from feedback from these choices and it should follow that as much as possible informed and conscious choices by adopters will lower innovation risks. Coverage of innovation risks must include Technological risks, Organizational and Societal Risks Market Risks Financial Risks and finally Turbulence Risks

4. State of the Art - Innovation Risk Management.

Effective management of innovation, as a theory, is as old as innovation activity. Innovation Risk Management is virtually new and immature (Olivia, et al., 2014). The current state of innovation management has not minimized failures in adoption and has not curtailed the continued increases in costs this could be for many reasons one of which certainly is incorrect selection and classification of the innovation risks at various stage gates (Koetzier, Alon, & Hooper), (Thun & Hoenig, 2011), (Olivia F. L., 2016). Innovation has done much to improve the life and society with more advantages than disadvantages. However, a new construct which includes risk management can address some of the shortcomings of innovation adoption and cost. There is much support and bodies of knowledge for supporting the managerial task of building innovation and innovation strategies levering the people skills behind it towards value creation and re-creation. But comprehensive texts on innovation risk management is yet to be scripted. What needs to be covered, but not yet is, is everything from design to servicing. Much like the wider research that is being done for this academic topic a wide cross section of innovation cases must be covered.

Innovation is important because it reduces inefficiencies and Frameworks are welcomed in this effort. The academic body of knowledge available for related topics rely heavily on cases from which frameworks are designed. It therefore should come as no surprize that the methodology is workable also for this hybrid risk innovation topic. The fast pace and dynamics of innovation increases risks; risks intrinsically linked to how innovation is adopted. Having a synthesis of the multiple dimensions involved in the innovation process is an imperative. Innovation risk management as a new theory would be the next valuable contribution to the tools set of business management. The application of risk management to innovation management has received increased attention since 2012, since this author conceived it as a potential academic research topic. Back in 2012 it was difficult to convince practitioners that any specific version of risk management was required for innovation activities. Today other research papers propose a similar path using methodological approaches against descriptive case studies supported by their own theoretical frameworks (Olivia, et al., 2014).

Innovation Risk Management as a new hybrid theory should like its composites cover the private and social impacts and include best practices, consider people skills and expertise as a factor, have coverage of financials, address adoption of the innovation as a success factor among other drivers to innovation success. Innovation Risk Management should enhance understanding, stimulate creativity, reduce complexity, provide diverse ways of problem framing, involve legal fiscal and regulatory, and facilitate consensus in occasion of innovation risk template application.

5. Conclusion

There is merit in having innovation risk management treated as a unique body of knowledge. The hybrid combination of the two leads to a symbiotic relationship with innovation management benefiting from risk management. The frameworks being suggested here and also as part of a larger research in progress aims to provide holistic risk focus from conception to adoption.

Five types of risks are considered in association with innovation: Technological risks, Organizational and Societal Risks Market Risks Financial Risks and finally Turbulence Risks (EU*Research, 2010). Other authors propose similar for example (Taplin, 2005), (Borge, 2001), nonetheless, whether we hedge them, diversify or leverage them, these risks must be owned and subjectively quantified by experts. The current work covered the merits of having innovation-risk management as a unique body of knowledge, highlighted the symbiotic relationship that innovation shares with risk management and presented also a proposal for building new frameworks for gathering, measuring and disclosing innovation-risk information.

An informal feedback gathered from practitioners in risk highlighted some of the weaknesses currently faced and point towards what the initial focus of innovation risk templates could be. Finally, the state of the art of innovation and risk shows room for having the hybrid theory with potential for benefits to be derived.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Assessment of 5S and Overall Equipment Effectiveness Contributions towards Promoting Total Productive Maintenance Implementation

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Abstract

The purpose of this paper is to assess the contributions of 5S and Overall Equipment Effectiveness (OEE) towards promoting Total Productive Maintenance (TPM) implementation in a particular manufacturing setting. For the purpose of this study, the key machines were selected from a specific manufacturing plant, which is considered as one of the leading industries in heavy duty equipment for quarries and mining applications. Production operations are identified as job-shop production system, which is characterized by custom made, low volume and high variety of products. The study focused on the 5S implementation as a first phase for the company to adopt the lean culture. The current OEEs of the plant's equipment are calculated for the key machines consisting of computerized numerical control (CNC) machines. 5S and OEE contribution were emphasized as the main elements to promoting TPM implementation. The benefits gained by the company was a significant improvement in the availability and performance of the equipment within the plant and improved housekeeping, environmental performance, health and safety standards in an integrated holistic way. The result obtained from the 5S implementation showed the OEE has improved for production cells from 55.89% to 63.46% which indicate that 5S and OEE would be strongly contributing towards supporting TPM program. Additional benefits were data collection improvement that led to an increase of 25.3% in production, and enhanced employee morale and job satisfaction.

Keywords: 5S, Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE).

1- Introduction

Under the unstable conditions in the global economy and intense competition in the domestic and global markets, the survival of companies depends on their ability to rapidly innovate and improve. From the maintenance perspective, this means finding ways to maximize equipment reliability and uptime, and extend plant and equipment life through cost effective maintenance. To achieve these objectives, industry must move away from the traditional reactive maintenance mode to proactive maintenance and management philosophies. Such changes require a complete shift in the maintenance approach to Total Productive Maintenance (TPM). In addition to this, Wireman (1991) stated that there is no single correct method for the implementation of a TPM program. Bamber et al. (1999) concluded that there is a complexity and divergence of TPM programs adopted throughout industry. In this paper, we consider the direct effect of 5S and OEE in promoting TPM. The outcome of this study would be beneficial to the participating company in terms of market share and competition, beside the library of knowledge relative to TPM in Canada context. Moreover, the main production machines have been evaluated and validated by employing OEE.

2- Literature review

Modern manufacturing requires that companies practice 5S philosophy to achieve the highest possible performance (Sharma & Singh, 2015). 5S is a direct and practical technique to build a lean culture at the workplace. It is relatively easy to undertake, and requires minimal additional resources. The first and small investment made in time and effort pays off in a much bigger manner when the results are realized and maintained. It should be taking into consideration that 5S and TPM are both born in Japan and therefore have roots in Japanese culture. Table 1 lists the five original Japanese words of 5S and the equivalent terms in

English. Unilever Canada Inc. won an award in 2009 (Award for TPM Excellence, Category A); it is the only single company across Canada that was TPM Award-winner during the years 2005 to 2012 (Abhishek et al., 2014; JIPM, 2015). Moreover, Researches or literature related to TPM in Canada is very limited; thus, it can be implied that TPM is still new to Canada Industry context.

As suggested by the Japanese institute plant maintenance (JIPM), the eight-pillar approach for TPM implementation includes autonomous maintenance, focused maintenance, planned maintenance, quality maintenance, education & training, safety, health & environment, office TPM, and development management (Ahuja & Khamba, 2008). The pillars of this approach, which are also supported by 5S, are shown in Figure 2. Moradi et al. (2011) studied the relationship between 5S and the pillars of TPM in one of the largest Iranian food factories. The findings confirmed that all 5S principles affected TPM providing a better way to reduce the six big losses and therefore, improve the OEE. Furthermore, one of the major goals of TPM and OEE programs is to reduce and/or eliminate the six big losses which are the most common causes of efficiency loss in manufacturing (Ranteshwar et al., 2012). Thus, the main goal of TPM is to increase equipment effectiveness which is a measure of the value added to production through equipment. In addition, a collaborative culture in the organization could be promoted in order to improve staff autonomous maintenance practices. However, to implement TPM, perseverance and determination are required. A detailed description of TPM pillars is beyond the scope of this paper.

Table 1: Meaning of 5S

Japanese Term	Equivalent 'S' term	English translation
Seiri	Sort	Organization
Seiton	Set in Order	Tidiness
Seiso	Shine	Cleaning
Seiketsu	Standardize	Standardization
Shitsuke	Sustain	Discipline

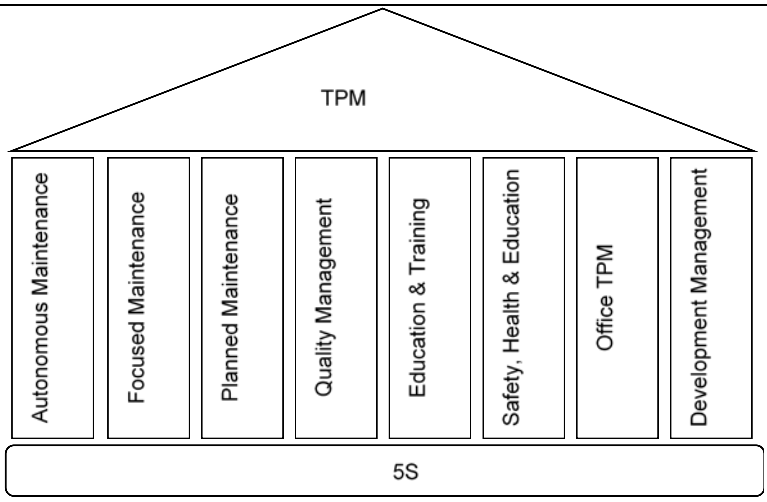

Figure 2: Illustration of the eight-pillar approach for TPM implementation (Ahuja & Khamba, 2008)

Bangar et al. (2013) stated that TPM focuses on maximizing the Overall Equipment Efficiency (OEE) with the involvement of everyone in the organization. It does not only establish a complete maintenance system, but also aims at improving the maintenance skills and knowledge among the shop-floor operators. OEE is a tool to measure the success of TPM implementation. OEE measurement is also commonly used as a key performance indicator (KPI) in conjunction with lean manufacturing efforts to provide an indicator of success. According to Robinson & Ginder (1995), OEE is a powerful component of the TPM process which clearly indicates the implementation progress and equipment performance. According to Nakajima (1989), OEE provides a strong start for introducing a pilot and subsequently an organization-wide TPM program. Nazimm et al. (2012) stated that OEE is a measure of equipment performance that is the indicator to which the equipment is doing what it is supposed to do. Six major losses can result from poor maintenance, faulty equipment, or inefficient operation.

The losses that are experienced by each industry are different. In general, these six losses are combined into one measure of Overall Equipment Effectiveness as shown in Figure 3, which is:

$$OEE = Equipment\ availbility\ \% \times Performance\ efficiency\ \% \times Quality\ rate\% \tag{1}$$

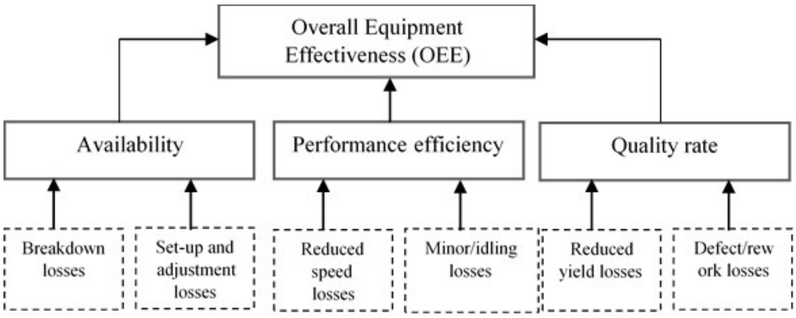

Figure 3: OEE Mode

3- Problem Definition

Historic organizational data showed that the six big losses such as breakdown, set-up, adjustment and defect loss were very high in value compared to the general manufacturing scenario. In other words, this indicates that the CNC machines considered in this research work were not utilized effectively; and hence, availability, quality, and performance rate were affected. The OEE value of the four CNC machines is shown in Figure 1. These machines had OEE percent of 71.23%, 62.72%, 63.95% and 25.65% respectively which were lower than world-class overall OEE 85%. Moreover, it indicated that the company must focus on enhancing the OEE. These machines are the key machines, and have been selected from the manufacturing plant to be the first to adopt and implement the 5S.

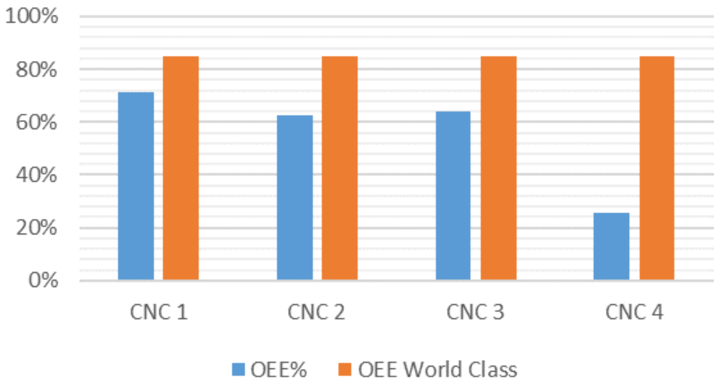

Figure 1: Comparison of the four machines OEE to the world class OEE

4- Problem Statement and Objective

According to the company's administration, some operational difficulties are being faced in the recent months. The key machines do not achieve the required efficiency level. Hence, the 5S implementation and OEE assessment is suggested to the company to facilitate lean culture program such as TPM philosophy. This study focused on achieving the following objectives:

- To support the 5S practices as a transition towards phasing in the lean culture.
- To assess the current stage of six major losses throughout the production system, which will be reflected into the OEE.
- To help building the foundation for a successful implementation of Total Productive Maintenance.

5- Methodology

5-1 Contributions of 5S implantation

The actual implementation of 5S practice is initiated by preparing and maintaining records of the jobs to be performed. Since each machine has several operators, only one operator is designated as a leader for each machine based on her/ his experience. The leaders for all the machines constitute a team that is responsible for implementing the 5S approach according to detailed tables/guidance designed for this purpose. According to the recommendations of each team, the leader for each work cell should set up an action plan for 5S implementation. After a month and as a first stage, the official Kick-off of 5S implementation in the CNC machine 1 or work cell 1 took place with a small ceremony to emphasize its importance. It would be a model for the rest of machines. Indeed, implementation of each item of 5S principles is considered an important step in contributing to the TPM successful implementation.

The 5S teams focused on the key machines and soon realized improvements through identifying abnormal conditions and consequently, a drop in the six big losses leading to improvement in the overall equipment effectiveness (OEE). 5S emphasizes on work environment and waste reduction and non-value activities, and improved quality, efficiency and safety. As a measure of the implementation of 5S, a follow-up document is developed to assess the progress level of all the 5S elements. Practicing 5S helped changing the operators' attitudes and revealed hidden faults that are usually not noticed.

5-2 Contributions of Overall Equipment Effectiveness (OEE)

To assess the effectiveness of the CNC machines, OEE was calculated before and during 5S implementation. Bamber et al. (1999) advocates that the main goal of TPM is to increase equipment effectiveness so it can be operated to its full potential and maintained at that level. The CNC machines suffer from losses that prevent effective operation. These losses could be caused by operator actions and equipment faults. In order to improve the effectiveness of the machines, it is important to recognize, measure and reduce these losses. Lean operation can be implemented on each machine by minimizing down time, defect, and the total maintenance cost. Furthermore, implementation of maintenance program based on lean operation and OEE improvement in production system are the major points of implementing TPM in industrial environment. Surely, this will help maintenance managers to understand the source of losses, their nature, and the suitable maintenance strategies to be adopted to reduce their effect. Nakajima (1989) divided the losses into six major categories as breakdown, set-up and adjustment losses, reduced speed, minor/idling losses, reduced yield losses, and defect/rework losses.

6- Analysis and Discussion

As mentioned previously, the four key machines were selected for the conduct of this study. A data sheet as shown in Table 3 was designed to track the production process of the 4 machines throughout the three shifts. The weekly data for each machine was the basis for important elements in OEE calculation. In addition, a monthly report was generated from the collected data. The data sheet focused on collecting information about availability, performance, and quality rates needed for OEE analysis.

Table 3: Data collected from the main production machines

Data	Units	Data	Units
Date	Day/month/ year	How much time	0000 Hrs.
Machine Status	Run-Setup- Maintenance	Machine cycle time	0000 Hrs.
Employee Number		Actual cycle time	0000 Hrs.
Job order	J0000000000	Ratio between machine time , actual cycle time	%
Machines name	M1	Employee Name	-------
Completed quantities	0000unit	Item name	-------
Number of defects	0000unit	item description	-------
Time start	Clock time	Reason for breakdown	-------
Time end	Clock time		

6-1 Availability Rate

Equipment availability is one of the important elements for calculating the OEE. It takes into account down-time loss, which includes non-scheduled breaks, breakdown, set up, adjustments, and operators' absence (that causes stopping planned production for an appreciable length of time). Availability is defined as the ratio of operating time to planned production time, and is calculated as:

$$Availability\ rate = \frac{Operating\ time}{Total\ piecesPlanned\ production\ time} \qquad (2)$$

Where:
Planned Production Time = Shift Length – Breaks, and Operating Time = Planned Production Time - Down Time.

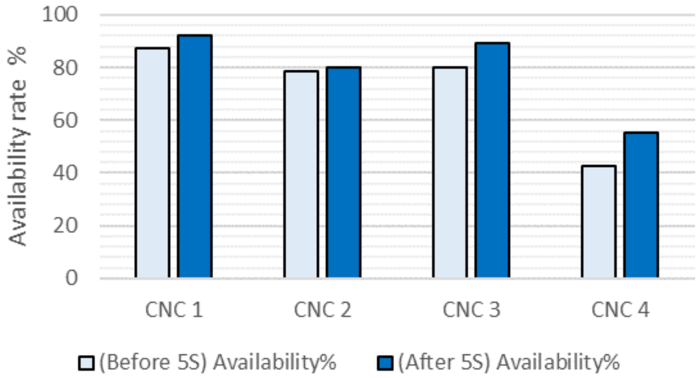

Figure 5: Availability rates (before & after 5S) for machine 1, 2, 3 and 4

Figure 5 illustrates the availability of the four machines before and after implementing the 5S. It can be seen that the availability of the first machine (CNC 1) reached 92.3% compared to 87.15%, after implementing 5S which means that it has achieved the world-class OEE score. Similarly, the availability of the other three machines (CNC 2, CNC 3, and CNC 4) reached 79.9%, 89.2%, and 55.3%, respectively, compared to 78.7%, 80%, and 42.7. These results illustrate the improvement made following the implementation of 5S. However, these machines have not achieved the world-class OEE score (~90%) and more work is still needed.

Availability rate improvements were achieved after 5S practice on production cells where operators took care of small maintenance tasks such as cleaning, inspecting and lubricating their equipment. This helps reducing downtime losses. As a result of 5S implementation and in a three-month period, the downtime loss for machine 1 has been reduced from 2160 minutes to 554.76 minutes. Also the downtime loss for machines 2, 3, and 4 downtime loss has gone down to 1446, 774.6 and 3980.16 minutes respectively, compared to the initial loss of 1536.6, 1401.8 and 4125 minutes. This certainly reflects the positive outcome of 5S implementation in these production machines.

6-2 Performance Rate

The performance rate of an equipment is defined as the ratio of the actual production output to its theoretical production output. Performance rate takes into account speed loss, which includes any factors that cause the process to operate at less than the maximum possible speed, when running, and is calculated as:

$$Performance\ rate = \frac{\left(\frac{Total\ pieces}{Operating\ Time}\right)}{Ideal\ Run\ Rate} \qquad (3)$$

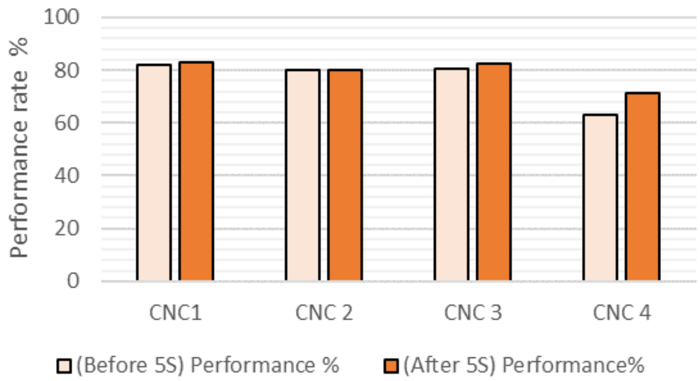

Figure 6: Performance rates (before & after 5S) for machine 1, 2, 3 and 4

Performance rates are slightly improved for all machines after 5S implementation. Figure 6 shows that machines 1 and 3 performed the best and reached to 82.8% and 82.3%, compared to the other two machines. However, there is no significant change detected in the performance of CNC 2 (80.2%) and CNC 4 (71.4%). Moreover, none of the four machines has achieved the world class OEE score for performance (95%). The poor performance indicator shows that the machines have some issues and need to be analyzed in more depth. Specifically, the issue seems to be in the ratio of actual run rate to ideal run rate which shows a percentage difference of about 17%. After 5S on place, the tool changes activity has been rearranged and labeled. This activity also became clearer and faster for operators to identify and practice tool changes. Hence, idling and minor stoppages time to some extent has reduced which it helped improving the performance rate.

6-3 Quality Rate

Another important element for the calculation of OEE is the quality rate. In this study, the quality rate was assessed based on the quality loss, which accounts for the produced pieces that do not meet the quality standards including the pieces that require rework. The quality rate is slightly improved for all four machines after the implementation of 5S. In this work, the quality rate was calculated as the ratio of good pieces to total pieces:

$$Quality\ rate = \frac{Number\ of\ good\ pieces}{Total\ pieces} \quad (4)$$

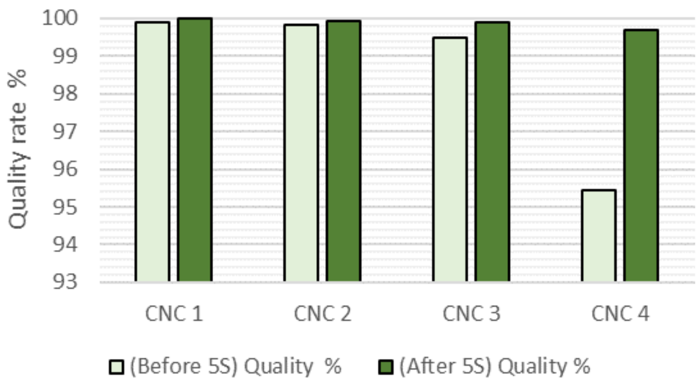

Figure 7: Quality rates (before & after 5S) for machine 1, 2, 3 and 4

Figure 7 shows the quality rate for each machine computed before and after the implementation of 5S. Generally, the quality rate before implementing 5S is really good in machines 1, 2, and 3 with rates of 99.9%, 99.8%, and 99.5%, while the quality rate is 95.4% in machine 4. However, the quality rate is slightly improved in three machines and one machine significantly improved as a result of the implementation of 5S to become 100%, 99.9%, 99.9%, and 99.7% for machines 1, 2, 3, and 4, respectively. These results indicate clearly that the quality rate of all machines has reached the world-class level. The improvements in the quality rate is related indirectly to the implementation of 5S. Specifically, implementation of 5S has caused a positive change in the attitude of the operators, which led to more careful monitoring of the products during the production process, handling with less damage, and identifying any signs of abnormalities earlier. The average for all machines, the quality rate increased from 98.8% to 99.9% as a result of lean culture implementation.

6-4 Overall Equipment Effectiveness (OEE)

As discussed earlier, the OEE calculation is based on availability, performance, and quality rates as given by Equation 1. The results used in the calculations are based on the average daily data of production per machine. Figure 8 shows the OEE for all the machines before and after the implementation of 5S. This figure clearly shows that the OEE values are improved for all machines. Moreover, the OEE reached 76.5%, 64.5%, 73.3%, and 39.3% for machines 1, 2, 3, and 4, respectively, after the implementation of 5S, which are less than world-class overall OEE 85% or better. Figure 8 shows that the first machine (CNC 1) has the best OEE value compared to the other machines, while the OEE of machines 2 and 3 are still low compared to the world-class overall OEE. For machine 4, although the OEE has increased from 25.7% to 39.3%, it still has a major problem in its performance that needs to be fixed, which is beyond the scope of this study.

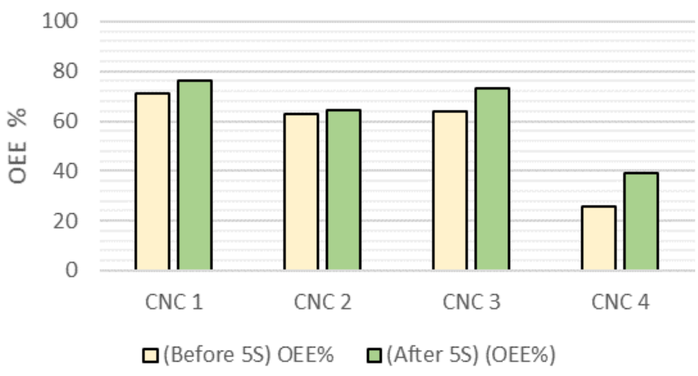

Figure 8: Comparison of OEE before & after implementing 5S

7- Conclusion

This study investigated the contributions of 5S and OEE towards supporting Total Productive Maintenance (TPM) implementation in a particular manufacturing setting. It is evident from the results that the daily time losses due to breakdown, set-up, adjustment, and defect loss of the CNC machines are indeed the major source of loss in time and money in the industrial environment. Moreover, the results revealed the amount of losses that the company was facing. However, it is found that all the machines under study do not face any serious problem with quality, manifested in less scrap and rework.

The OEE values of the machines are considered low compared to the world-class OEE score. These results have promoted more operators' involvement in performing 5S activities, which helped in generating the sense and the importance of tidiness among them. It can also be concluded that 5S implementation, not only led to increasing the OEE, but also prepared the plant for the TPM implementation in order to, hopefully, achieve the world-class OEE level. The most important achievement of the implementation of 5S in this study is the intensification of the employees' awareness of lean manufacturing culture, which will be an important foundation for TPM implementation. On the average for all CNC machines, OEE has improved from 55.8% to 63.4% indicating an improvement in equipment availability, performance efficiency and improvement in quality of product. Now most important part for the company is to maintain a continuous improvement program.

Acknowledgements

The authors would like to acknowledge the Natural Sciences and Engineering Research Council of Canada (NSERC) for the financial support provided to conduct this study by promoting an active liaison between industry and universities.

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Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Hybrid Multi-criteria Decision Making Approach Based on Fuzzy AHP and Fuzzy TOPSIS Methods for the Stock Area Selection Problem

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Abstract

This study considers a stock area selection problem of an automotive company which includes limited space. The stock area selection problem of the company consists of alternative locations which have different technical features and some specific criteria to select the locations. Additionally more than one alternative area can be constructed in the company to store a certain amount of stock. The aim of the problem is to find best stock areas from the alternatives that will be constructed. In order to solve the problem two hybrid approaches are proposed by integrating a fuzzy multi-criteria decision making method within a 0-1 goal programming (GP) model. The main difference between the hybrid approaches is the multi-criteria decision making methods used in the solution procedure where the considered methods are a fuzzy AHP (Analytic Hierarchy Process) method and a fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) method. Each hybrid approach consist of two stage: First, qualitative criteria are taken into account according to the selected fuzzy multi-criteria decision making method and then a 0-1 GP model is operated by considering the criteria weights obtained in the first stage. Finally, the alternative stock areas are selected by comparing the results of two hybrid approaches. As a result of the case study specified for the automotive company, the best alternatives are selected to construct by executing the proposed solution procedure.

Keywords

Stock area selection, multi-criteria decision making, fuzzy AHP, fuzzy TOPSIS, goal programming

1. Introduction

Facility layout planning is a critical issue for the companies because of its directly effects on the operational productivity and efficiency of a facility (Yang & Hung, 2007). At this stage, managers have to take into account various criteria so as to obtain best layout plan where most of them cannot be measured exactly because of their uncertainty. Due to its significant impacts on the performance of manufacturing systems, the facility layout planning problem with multiple criteria has been commonly studied by researchers (Deb & Bhattacharyya, 2003). Moreover, several approaches are proposed for different type of facility layout problems, which aims to find effective solutions by satisfying a set of constraints or performance objectives. Also it is shown that a good layout design obtained with an appropriate solution approach contributes to the overall efficiency of operations by having a great potential to reduce until 50% the total operating costs (Drira, Pierreval, & Hajri-Gabouj, 2007).

In this study, a stock area selection problem of an automotive company is considered which aims to evaluate best selection from the alternatives by considering both qualitative and quantitative criteria. In order to solve the stock area selection problem of the company, this study introduces two hybrid approaches: A hybrid fuzzy AHP (Analytic Hierarchy Process) method and a hybrid fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) method. For each method, the measurement of the alternatives and decision making process are carried out into two steps. First, qualitative criteria are taken into account according to the selected fuzzy multi-criteria decision making (MCDM) method by using triangular fuzzy numbers. Then a 0-1 goal programming (GP) model is operated by considering the alternative weights obtained in the first stage and other quantitative constraints. Finally, the best location set is selected by comparing the results of two hybrid methods. In computational studies, the proposed methods are implemented to the real-life problem of the company which consist of eight qualitative and three quantitative criteria to select best location set from five alternative areas.

The rest of the paper is organized as follows: Section 2 presents the literature review part for the AHP, fuzzy AHP, TOPSIS, fuzzy TOPSIS and GP methods. Section 3 describes the problem and Section 4 introduces the proposed methodology consist of hybrid fuzzy AHP and hybrid fuzzy TOPSIS methods. Moreover, application of the proposed method to case study is given in Section 4. Finally, conclusions and discussions are presented in Section 5.

2. Literature Review

Most of the studies in literature have been considered the location selection or facility layout problem based on the quadratic assignment problem with an objective function to minimize total transportation or cost maximize total closeness ratings. Moreover, due to the complexity of the problem, various heuristic and meta-heuristic approaches are proposed to solve problem (Deb & Bhattacharyya, 2005; Yang & Kuo, 2003). However, stock area selection decision involve several qualitative and quantitative criteria and it is often necessary to select among possibly conflicting and multiple objectives. Therefore, the multiple criteria decision making becomes a useful approach for solving this kind of problem. AHP and TOPSIS are two of the most commonly used MCDM methods. AHP is firstly introduced by Saaty (1977, 1990) as a model and then applied widely to several complex decision problems, such as supplier selection (Bruno, Esposito, Genovese, & Passaro, 2012; Chan & Chan, 2010; Levary, 2008), technology investment (Karaarslan & Gundogar, 2009; Sloane, Liberatore, Nydick, Luo, & Chung, 2003), project management (Al-Harbi, 2001; Muralidhar, Santhanam, & Wilson, 1990), energy policy (Chatzimouratidis & Pilavachi, 2009; Kablan, 2004), location design (Aras, Erdoğmuş, & Koç, 2004; Boardman Liu, Berger, Zeng, & Gerstenfeld, 2008; Yang & Lee, 1997). TOPSIS, proposed by Hwang & Yoon (1981), choose alternatives that have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution. TOPSIS is a widely adopted decision support technique in management research. For example, Bulgurcu (2012) applied TOPSIS to evaluate the performances of firms by using the financial tables. These firms are examined and assessed in terms of ten financial ratios. Pal and Choudhury (2009) evaluated the relative performance of the banks across the service quality dimensions using TOPSIS.

Fuzzy set theory combined with MCDM methods has been extensively used to deal with uncertainty, subjectivity, and ambiguity in the decision process. Fuzzy AHP (Ayağ & Özdemir, 2006; Huang, Chu, & Chiang, 2008; Kahraman, Cebeci, & Ulukan, 2003; Kreng & Wu, 2007) and Fuzzy TOPSIS (Chamodrakas & Martakos, 2012; Krohling & Campanharo, 2011; Yong, 2006) has been broadly used in MCDM studies.

GP, originally introduced by Charnes and Cooper (1957), is a mathematical approach that capable of handling multiple objectives with a priori articulation of the preference information (Khalili-Damghani, Sadi-Nezhad, & Tavana, 2013). MCDM techniques can be used as an effective tool together or combined with GP to take into account both qualitative and quantitative criteria. There are various studies that used the AHP and GP together in the literature (Badri, 2001; Schniederjans & Wilson, 1991; Yurdakul, 2004). A similar approach which involved TOPSIS and GP used by some authors (Li, Chen, & Fu, 2008; Ramezani, Bashiri, & Atkinson, 2011). There are also other studies that used the AHP/TOPSIS and GP together under fuzzy environment (Liao & Kao, 2011; Yu, 2002).

3. Problem Description

This study is carried out in a paintshop department of an automotive company. Besides the painting process of the carbodies, this department also includes various operations to avoid corrosion on body, outflow at joining surfaces, noise arisen by vibration, etc. The carbodies are transported between the stations for these operations on a conveyor carrier system via an auxiliary equipment called as “luge” where the total number of luges in department is 579. After the painting operations, the luges loaded with a painted carbody are transferred from paintshop to temporary storage area for assembly process. According to the assembly order, the painted carbodies are sent to the assembly department by switching the paintshop luge with an assembly luge. At this stage, the idle luges are transferred back to the initial station of the department if a new carbody arrives to the paintshop department. Otherwise, the idle luges are moved manually by workers to the luge stocking area whose capacity is 111 or to any location if the stocking area is full. In addition to the inefficient workforce utilization, these movements also cause a physical and chemical deformation on the luges, which exposes additional cost for the firm. Because of the existing stocking area is insufficient and manual movements deforms the luges, the firm wants to construct two new stocking areas by choosing from five alternative locations ($A1$, $A2$, $A3$, $A4$, and $A5$) with different capacities and properties. In order to make best selection to construct stocking areas, the firm described various criteria to evaluate the ratings of the alternatives which are categorized into two groups:

qualitative and quantitative criteria. For the quantitative criteria, the stock area capacity, investment cost and depreciation of the investment are considered, while the qualitative criteria are described as follows:

1. Criticality ($C1$)
2. Location ($C2$)
3. Feasibility ($C3$)
4. Availability ($C4$)
5. Maintenance ($C5$)
6. Construction period ($C6$)
7. Processing time for stocking ($C7$)
8. Energy requirement ($C8$)

4. Proposed Methodology

In order to solve the stock area selection problem of the company, two hybrid methods using fuzzy AHP and fuzzy TOPSIS are presented in this study. Each hybrid method consists of two stage. In the first stage, a fuzzy multi-criteria method is operated for the qualitative criteria with linguistic definitions. Following the multi-criteria decision making process, a 0-1 GP is performed by considering the alternative weights obtained in the first stage and other quantitative constraints. Figure 1 represents the framework of the proposed solution procedure for the stock area selection problem. The steps of the solution methodology and their application to the real-life problem of the company are presented with the following subsections.

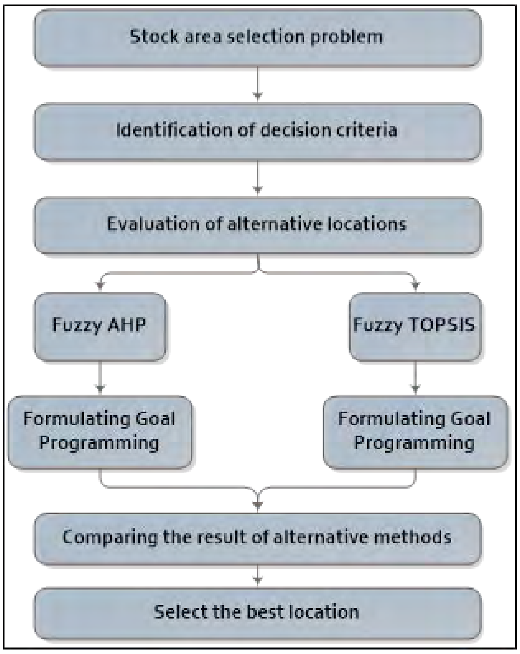

Figure 1: The framework of the proposed solution procedure

4.1. Fuzzy AHP

The fuzzy AHP method, which is widely used as a decision making procedure in various multi-criteria decision making problems, embed the fuzzy theory to basic AHP methods. Distinctly from the AHP, this method uses linguistic variables to take the pair-wise comparisons of different alternatives with respect to various criteria. In this study, the fuzzy AHP method proposed by Chang (1996) which utilizes a triangular fuzzy set in its process is used for the first hybrid method. Table 1 shows the triangular fuzzy scales applied for the stock area selection problem (Vahidnia, Alesheikh, & Alimohammadi, 2009). With respect to these fuzzy set, the comparison matrix for criteria and alternatives are formed by applying an interview to three decision makers of the company, which are presented in Appendix A. As a result of the fuzzy AHP method, the scores of the criteria are determined as follows: 0.41, 0.46, 0.05, 0.00, and 0.08. Hence, the sequence of the alternatives is $A2 \succ A1 \succ A5 \succ A3 \succ A4$.

Table 1: Linguistic variables used for the fuzzy AHP method

Linguistic Definition	Fuzzy Triangular Scale	Reciprocal of the Scale
Equally Important	(1, 1, 1)	(1/1, 1/1, 1/1)
The Intermittent Value	(1, 2, 3)	(1/3, 1/2, 1/1)
Weakly Important	(2, 3, 4)	(1/4, 1/3, 1/2)
The Intermittent Value	(3, 4, 5)	(1/5, 1/4, 1/3)
Fairly Important	(4, 5, 6)	(1/6, 1/5, 1/4)
The Intermittent Value	(5, 6, 7)	(1/7, 1/6, 1/5)
Strongly Important	(6, 7, 8)	(1/8, 1/7, 1/6)
The Intermittent Value	(7, 8, 9)	(1/9, 1/8, 1/7)
Absolutely Important	(9, 9, 9)	(1/9, 1/9, 1/9)

4.2. Fuzzy TOPSIS

For the second solution procedure, the fuzzy TOPSIS method proposed by C.-T. Chen (2000) is considered to solve multi-criteria decision making problem. In this method, the linguistic variables are used by decision makers to assess the weights of the criteria and the ratings of the alternatives. These linguistic variables proposed by C.-T. Chen (2000) are expressed with triangular fuzzy numbers as shown in Table 2. With respect to these linguistic definitions, the importance weight of the criteria and the ratings of the alternatives according to all criteria are presented in Appendix B. As a result of the fuzzy TOPSIS method, the normalized scores of the criteria are determined as follows: 0.26, 0.25, 0.19, 0.08, and 0.22. Hence, the sequence of the alternatives is $A1 \succ A2 \succ A5 \succ A3 \succ A4$.

Table 2: Linguistic variables used for the Fuzzy TOPSIS method

Linguistic Definition	Fuzzy Triangular Weights
Very Low (VL)	(0.0, 0.0, 0.1)
Low (L)	(0.0, 0.1, 0.3)
Medium Low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very High (VH)	(0.9, 1.0, 1.0)

4.3. Goal Programming

After the first stage of the proposed solution methodology, a 0-1 GP proposed by R.-S. Chen and Shyu (2006) is employed, which takes into account the outputs of the multi-criteria decision making method as a special constraint in model. The aim of the model is to find best selection that minimizes total derivation from the target values. The notations and model formulation are given as follows:

Parameters

G set of goals

A set of alternatives

t_i target value of the goal i; $\forall i \in G$

w_i^+ weight of the goal i in objective function for positive deviations; $\forall i \in G$

w_i^- weight of the goal i in objective function for negative deviations; $\forall i \in G$

a_{ij} coefficient of alternative i for goal j in technological constraints; $\forall i \in G; \forall j \in A$

s the number of alternatives in which a choice have to made

Decision Variables

x_j is a binary variable and equal to 1 is if the alternative j is constructed as a stock area, otherwise 0; $\forall j \in A$

d_i^+ is a positive variable and indicates the positive deviations from goal i; $\forall i \in G$

d_i^- is a positive variable and indicates the negative deviations from goal i; $\forall i \in G$

Model

$$Min\ Z = \sum_{i \in G} w_i^+ d_i^+ + \sum_{i \in G} w_i^- d_i^- \quad (1)$$

Subject to

$$\sum_{j \in A} a_{ij} x_j - d_i^+ + d_i^- = t_i \qquad \forall i \in G \quad (2)$$

$$\sum_{j \in A} x_j = s \quad (3)$$

$$x_j \in \{0,1\} \qquad \forall j \in A \quad (4)$$

$$d_i^+, d_i^- \geq 0 \qquad \forall i \in G \quad (5)$$

Equation (1) identifies the objective function which aims to minimize total weighted deviations from the goals. Equation (2) describes the goals of the problem and also computes the positive and negative deviations from the goals. Equation (3) ensures that the selected alternative area to be constructed must be equal to s. Equation (4) and (5) describe the binary and positive variables, respectively.

According to the solutions of the fuzzy AHP and fuzzy TOPSIS methods, the 0-1 GP model parameters are organized as shown in Table 3, and the parameter s is set to 2. The weights of the criteria in Table 3 are defined with respect to the prescience of the decision makers. The presented 0-1 GP is solved by using both of the fuzzy AHP and fuzzy TOPSIS methods. The results of the model which are given in Table 4 shows that $A2$ and $A4$ are the most suitable areas to construct as a stock area in company.

Table 3: Problem data for the 0-1 GP models

Goals		w_i^+	w_i^-	a_{ij}					t_i
				***A*1**	***A*2**	***A*3**	***A*4**	***A*5**	
Quantitative Criteria	Capacity	0	5	128	66	300	384	160	600
	Cost	10	0	5000	2000	7000	8000	4000	10000
	Depreciation	1	0	0.65	0.35	0.88	1.40	0.44	1.00
Method	Fuzzy AHP	10	10	0.41	0.46	0.05	0.00	0.08	1.00
	Fuzzy TOPSIS			0.26	0.25	0.19	0.08	0.22	

Table 4: Results of the 0-1 GP models

Model	**Binary Decision Variables**					**Objective Function Value**	**Derivation from the Target**			
	x_1	x_2	x_3	x_4	x_5		***G*1**	***G*2**	***G*3**	***G*4**
Model 1 (Used fuzzy AHP solution)	0	1	0	1	0	756.15	150	0	0.75	0.54
Model 2 (Used fuzzy TOPSIS solution)	0	1	0	1	0	757.35				0.66

5. Discussion and Conclusion

Facility layout planning, is considered as a long-term decision making process and critical for the companies by having potential to increase operational productivity. Therefore, the layout plans have to be formed by considering various qualitative and quantitative criteria. In this study, a stock area selection problem of an automotive company is studied as a real-life problem which aims to evaluate best stock area selection from the alternatives by taking into account both qualitative and quantitative criteria. To solve the case study of the company, this paper proposes two fuzzy hybrid approaches (fuzzy AHP and fuzzy TOPSIS) by integrating a multi-criteria decision making method within a 0-1 GP model. Each solution procedure consists of two stage: First, the problem is solved by using a fuzzy multi-criteria decision making method to obtain a rate for the alternatives with respect to the qualitative criteria. Then, the problem is solved by using 0-1 GP model regarding the results of the multi-criteria decision making scores as a special constraint. As a result of the hybrid fuzzy AHP and hybrid fuzzy TOPSIS methods, where the solutions of the approaches are similar, second and fourth alternatives are selected as a stock area for the company. According to the selected alternatives, an extra 450 carrier capacity is provided for the company within the investment cost limit.

Appendix A. Input data for fuzzy AHP method

Table A1: Comparison matrix for criteria

Criteria	*C*1	*C*2	*C*3	*C*4	*C*5	*C*6	*C*7	*C*8
***C*1**	(1.0, 1.0, 1.0)	(0.8, 1.5, 2.3)	(1.0, 2.0, 3.0)	(2.3, 3.0, 3.7)	(2.7, 3.7, 4.7)	(5.0, 6.0, 7.7)	(5.7, 7.0, 7.7)	(8.3, 8.7, 9.0)
***C*2**	(0.6, 1.0, 1.7)	(1.0, 1.0, 1.0)	(1.7, 2.3, 3.0)	(1.7, 2.7, 3.7)	(3.0, 4.0, 5.5)	(5.3, 6.0, 6.7)	(5.7, 6.7, 7.7)	(7.7, 8.3, 9.0)
***C*3**	(0.3, 0.5, 1.0)	(0.5, 0.6, 0.8)	(1.0, 1.0, 1.0)	(1.8, 2.5, 3.3)	(2.0, 3.0, 4.0)	(4.7, 5.7, 6.7)	(5.0, 6.0, 7.0)	(7.3, 7.7, 8.0)
***C*4**	(0.5, 0.5, 0.6)	(0.3, 0.4, 0.7)	(0.5, 0.9, 1.3)	(1.0, 1.0, 1.0)	(0.8, 1.5, 2.3)	(2.7, 3.7, 4.7)	(2.7, 3.7, 4.7)	(4.3, 5.3, 7.0)
***C*5**	(0.2, 0.3, 0.4)	(0.2, 0.3, 0.5)	(0.3, 0.4, 0.6)	(0.6, 1.0, 1.7)	(1.0, 1.0, 1.0)	(2.0, 3.0, 4.0)	(2.3, 3.3, 4.3)	(4.3, 5.3, 6.3)
***C*6**	(0.1, 0.2, 0.2)	(0.1, 0.2, 0.2)	(0.2, 0.2, 0.2)	(0.2, 0.3, 0.6)	(0.3, 0.4, 0.6)	(1.0, 1.0, 1.0)	(1.1, 1.8, 2.7)	(2.3, 3.0, 3.7)
***C*7**	(0.1, 0.2, 0.2)	(0.1, 0.2, 0.2)	(0.2, 0.2, 0.3)	(0.2, 0.3, 0.4)	(0.2, 0.3, 0.6)	(0.5, 0.9, 1.5)	(1.0, 1.0, 1.0)	(1.0, 2.0, 3.0)
***C*8**	(0.1, 0.1, 0.1)	(0.1, 0.1, 0.1)	(0.1, 0.1, 0.2)	(0.2, 0.2, 0.2)	(0.2, 0.2, 0.2)	(0.5, 0.5, 0.6)	(0.3, 0.5, 1.0)	(1.0, 1.0, 1.0)

Table A2: Comparison matrix of alternatives with respect to the criteria

		Alternatives				
Criteria	**Alternatives**	***A*1**	***A*2**	***A*3**	***A*4**	***A*5**
*C*1	*A*1	(1.0, 1.0, 1.0)	(0.5, 0.9, 1.4)	(37, 4.3, 5.0)	(6.3, 7.3, 7.7)	(1.4, 2.1, 2.8)
	*A*2	(1.8, 2.5, 3.3)	(1.0, 1.0, 1.0)	(40, 5.0, 6.0)	(6.7, 7.7, 8.7)	(3.0, 4.0, 5.0)
	*A*3	(0.4, 0.5, 0.5)	(0.2, 0.2, 0.3)	(1.0, 1.0, 1.0)	(4.3, 5.3, 6.3)	(0.5, 0.6, 0.8)
	*A*4	(0.1, 0.2, 0.2)	(0.1, 0.1, 0.2)	(0.2, 0.2, 0.2)	(1.0, 1.0, 1.0)	(0.2, 0.2, 0.3)
	*A*5	(0.8, 1.3, 1.8)	(0.2, 0.3, 0.5)	(1.7, 2.3, 3.0)	(4.0, 5.0, 6.0)	(1.0, 1.0, 1.0)
*C*2	*A*1	(1.0, 1.0, 1.0)	(0.5, 0.9, 1.5)	(4.3, 5.0, 5.7)	(6.0, 6.7, 7.3)	(1.4, 2.2, 3.0)
	*A*2	(1.1, 1.8, 2.7)	(1.0, 1.0, 1.0)	(4.0, 5.0, 6.0)	(6.3, 7.3, 8.3)	(1.7, 2.0, 2.3)
	*A*3	(0.4, 0.4, 0.4)	(0.2, 0.2, 0.3)	(1.0, 1.0, 1.0)	(3.7, 4.7, 5.7)	(0.3, 0.4, 0.7)
	*A*4	(0.2, 0.2, 0.3)	(0.1, 0.1, 0.2)	(0.2, 0.2, 0.3)	(1.0, 1.0, 1.0)	(0.2, 0.3, 0.5)
	*A*5	(0.5, 0.9, 1.4)	(0.7, 0.8, 0.8)	(1.7, 2.7, 3.7)	(2.7, 3.7, 4.7)	(1.0, 1.0, 1.0)
*C*3	*A*1	(1.0, 1.0, 1.0)	(1.0, 2.0, 3.0)	(3.0, 3.7, 4.3)	(5.0, 5.7, 6.3)	(1.7, 2.7, 3.7)
	*A*2	(0.3, 0.5, 0.7)	(1.0, 1.0, 1.0)	(2.1, 2.4, 2.8)	(4.3, 5.3, 6.3)	(1.7, 2.0, 2.3)
	*A*3	(0.5, 0.5, 0.7)	(1.0, 1.4, 1.7)	(1.0, 1.0, 1.0)	(4.3, 5.3, 6.3)	(1.1, 1.4, 1.8)
	*A*4	(0.2, 0.2, 0.3)	(0.2, 0.2, 0.3)	(0.2, 0.2, 0.3)	(1.0, 1.0, 1.0)	(0.2, 0.3, 0.4)
	*A*5	(0.3, 0.4, 0.8)	(0.7, 0.8, 0.8)	(1.4, 1.8, 2.2)	(2.7, 3.7, 4.7)	(1.0, 1.0, 1.0)
*C*4	*A*1	(1.0, 1.0, 1.0)	(0.8, 1.1, 1.5)	(3.7, 4.3, 5.7)	(7.0, 7.3, 7.7)	(1.8, 2.4, 3.2)
	*A*2	(1.1, 1.5, 2.0)	(1.0, 1.0, 1.0)	(3.7, 4.7, 5.7)	(7.0, 7.7, 8.3)	(1.7, 2.3, 3.0)
	*A*3	(0.4, 0.4, 0.5)	(0.2, 0.2, 0.3)	(1.0, 1.0, 1.0)	(3.7, 4.7, 5.7)	(0.3, 0.3, 0.5)
	*A*4	(0.1, 0.2, 0.2)	(0.1, 0.1, 0.2)	(0.2, 0.2, 0.3)	(1.0, 1.0, 1.0)	(0.2, 0.3, 0.5)
	*A*5	(0.8, 1.2, 1.6)	(0.5, 0.6, 0.7)	(2.0, 3.0, 4.0)	(3.3, 4.3, 5.3)	(1.0, 1.0, 1.0)
*C*5	*A*1	(1.0, 1.0, 1.0)	(1.3, 2.0, 2.7)	(5.0, 6.0, 7.0)	(8.3, 8.7, 9.0)	(2.3, 3.0, 3.7)
	*A*2	(0.5, 0.6, 0.8)	(1.0, 1.0, 1.0)	(4.7, 6.0, 7.3)	(7.3, 8.0, 8.7)	(2.0, 2.7, 3.3)
	*A*3	(0.1, 0.2, 0.2)	(0.1, 0.2, 0.2)	(1.0, 1.0, 1.0)	(3.3, 4.3, 5.3)	(0.2, 0.3, 0.4)
	*A*4	(0.1, 0.1, 0.1)	(0.1, 0.1, 0.1)	(0.2, 0.2, 0.3)	(1.0, 1.0, 1.0)	(0.2, 0.2, 0.3)
	*A*5	(0.5, 0.5, 0.6)	(0.5, 0.5, 0.6)	(3.0, 4.0, 5.0)	(5.0, 5.7, 6.3)	(1.0, 1.0, 1.0)
*C*6	*A*1	(1.0, 1.0, 1.0)	(1.7, 2.4, 3.1)	(6.3, 7.0, 8.3)	(5.7, 7.0, 8.3)	(4.1, 4.8, 5.5)
	*A*2	(1.2, 1.5, 2.2)	(1.0, 1.0, 1.0)	(5.3, 6.3, 7.3)	(5.0, 6.0, 7.0)	(3.0, 4.0, 5.0)
	*A*3	(0.1, 0.2, 0.2)	(0.1, 0.2, 0.2)	(1.0, 1.0, 1.0)	(0.8, 0.8, 0.8)	(0.3, 0.4, 0.8)
	*A*4	(0.1, 0.2, 0.2)	(0.1, 0.2, 0.2)	(1.3, 1.7, 2.0)	(1.0, 1.0, 1.0)	(0.3, 0.4, 0.6)
	*A*5	(0.8, 1.1, 1.4)	(0.2, 0.3, 0.5)	(1.7, 2.7, 3.7)	(2.0, 3.0, 4.0)	(1.0, 1.0, 1.0)
*C*7	*A*1	(1.0, 1.0, 1.0)	(0.2, 0.3, 0.4)	(3.4, 4.0, 4.7)	(3.4, 4.0, 4.7)	(3.7, 4.7, 5.7)
	*A*2	(2.3, 3.3, 4.3)	(1.0, 1.0, 1.0)	(4.4, 5.4, 5.8)	(4.4, 4.8, 5.1)	(5.0, 6.0, 7.0)
	*A*3	(2.4, 2.8, 3.1)	(0.7, 1.1, 1.4)	(1.0, 1.0, 1.0)	(1.2, 1.6, 2.2)	(2.4, 2.8, 3.2)
	*A*4	(2.1, 2.5, 2.8)	(1.1, 1.4, 1.8)	(1.1, 1.8, 2.4)	(1.0, 1.0, 1.0)	(2.4, 3.1, 3.8)
	*A*5	(0.2, 0.2, 0.3)	(0.1, 0.2, 0.2)	(1.0, 1.4, 1.7)	(1.5, 1.8, 2.2)	(1.0, 1.0, 1.0)
*C*8	*A*1	(1.0, 1.0, 1.0)	(2.3, 3.3, 4.3)	(1.4, 1.7, 2.1)	(2.7, 3.1, 3.4)	(3.4, 4.1, 4.8)
	*A*2	(0.3, 0.4, 0.7)	(1.0, 1.0, 1.0)	(0.2, 0.3, 0.6)	(2.1, 2.5, 3.2)	(1.1, 1.8, 2.4)
	*A*3	(1.7, 2.1, 2.4)	(2.3, 3.3, 4.3)	(1.0, 1.0, 1.0)	(2.5, 2.9, 3.4)	(2.1, 2.8, 3.7)
	*A*4	(1.4, 1.7, 2.0)	(2.4, 3.0, 3.7)	(1.4, 2.0, 2.7)	(1.0, 1.0, 1.0)	(2.7, 3.4, 4.1)
	*A*5	(1.4, 1.8, 2.2)	(1.2, 1.6, 2.2)	(0.5, 0.8, 1.2)	(1.1, 1.5, 2.0)	(1.0, 1.0, 1.0)

Appendix B. Input data for fuzzy TOPSIS

Table B1: The importance weight of the criteria

Criteria	Decision Maker 1	Decision Maker 2	Decision Maker 3
*C*1	VH	H	VH
*C*2	H	VH	H
*C*3	H	MH	H
*C*4	MH	H	M
*C*5	M	M	MH
*C*6	ML	L	ML
*C*7	L	ML	L
*C*8	VL	L	VL

Table B2: The ratings of the five alternatives according to all criteria

Criteria	Alternatives	Decision Maker 1	Decision Maker 2	Decision Maker 3
*C*1	*A*1	H	VH	MH
	*A*2	VH	H	VH
	*A*3	ML	M	MH
	*A*4	VL	ML	L
	*A*5	MH	M	H
*C*2	*A*1	H	VH	M
	*A*2	VH	H	MH
	*A*3	ML	MH	M
	*A*4	ML	L	VL
	*A*5	M	H	MH
*C*3	*A*1	MH	H	VH
	*A*2	M	MH	M
	*A*3	MH	H	M
	*A*4	VL	L	L
	*A*5	H	MH	M
*C*4	*A*1	VH	MH	H
	*A*2	VH	H	H
	*A*3	MH	MH	M
	*A*4	ML	VL	L
	*A*5	M	H	MH
*C*5	*A*1	VH	MH	H
	*A*2	VH	H	H
	*A*3	M	ML	MH
	*A*4	ML	VL	L
	*A*5	MH	M	H
*C*6	*A*1	H	MH	H
	*A*2	H	H	VH
	*A*3	M	ML	M
	*A*4	ML	ML	MH
	*A*5	MH	H	M
*C*7	*A*1	MH	M	H
	*A*2	M	MH	M
	*A*3	H	VH	MH
	*A*4	VH	H	H
	*A*5	M	ML	L
*C*8	*A*1	MH	H	H
	*A*2	H	MH	VH
	*A*3	MH	H	M
	*A*4	VL	L	L
	*A*5	M	MH	M

Acknowledgements

The authors would like to thank to the case study company for the research opportunity and Kemal Alper for supplying the necessary data and for his valuable support to this study.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Performance Analysis of Meta-heuristic Algorithms for a Quadratic Assignment Problem

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Abstract

A quadratic assignment problem (QAP) is a combinatorial optimization problem that belongs to the class of NP-hard ones. So, it is difficult to solve in the polynomial time even for small instances. Research on the QAP has thus focused on obtaining a method to overcome this problem. Heuristics and meta-heuristics algorithm are prevalent solution methods for this problem. This paper is one of comparative studies to apply different meta-heuristic algorithms for solving the QAP. One of the most popular approaches for categorizing meta-heuristic algorithms is based on a search strategy, including (1) local search improvement meta-heuristics and (2) global search-based meta-heuristics. The matter that distinguishes this paper from the other is the comparative performance of local and global search (both EA and SI), in which meta-heuristics that consist of genetic algorithm (GA), particle swarm optimization (PSO), hybrid GA-PSO, grey wolf optimization (GWO), harmony search algorithm (HAS) and simulated annealing (SA). Also, one improvement heuristic algorithm (i.e., 2-Opt) is used to compare with others. The PSO, GWO and 2-Opt algorithms are improved to achieve the better comparison toward the other algorithms for evaluation. In order to analysis the comparative advantage of these algorithms, eight different factors are presented. By taking into account all these factors, the test is implemented in six test problems of the QAP Library (QAPLIB) from different sizes. Another contribution of this paper is to measure a strong convergence condition for each algorithm in a new way.

Keywords

Quadratic assignment problem; Meta-heuristic algorithm; Performance analysis; QAPLIB.

1. Introduction

The quadratic assignment problem (QAP) is a combinatorial optimization problem, which is presented by (Koopmans et al., 1957). The general QAP locates facilities with respect to the cost minimization of the placing facility and distances from other facilities where flow exists between every pair of facilities. The QAP belongs to the class of NP-hard problems. Therefore, exact solutions have been incompatible for the QAP in large-sized instances, because they need a large amount of computational time for solving this problem (Bayat & Sedghi, 2009).

Loiola et al. (2007) proposed a survey about tendencies for 50 year studies of the QAP and categorized this study in the application, theory and algorithms. This tendency is shown in the period 1990 to 2005 in Figure 1. This paper has shown the number of publications in algorithm design is more than two others subjects. Also, recent surveys on QAP proposed by Bhati and Rasool (2014) that described some applications of the QAP, which have been applied to real world problems. Bayat and Sedghi (2009) presented a complete survey on the QAP about the variance formulation of the problem and different solution methods. Heuristic and meta-heuristic algorithms are the best guide for obtaining the feasible or a good solution for large instances; however, this solution usually is near optimal.

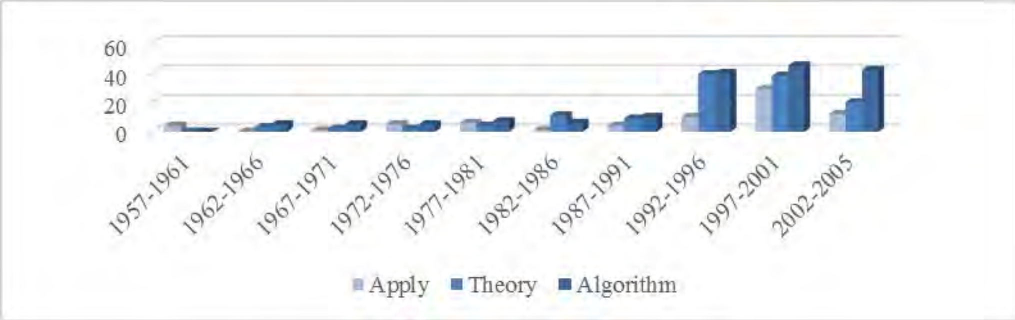

Figure 1: Number of 59 year publication in the QAP for these categorizes (Loiola et al., 2007)

There have been used several meta-heuristics to solve the QAP, in which some examples are mentioned, such as scatter search (SS) by Cung et al. (1997) and greedy randomized adaptive search procedure (GRASP) by Oliveira et al. (2004). Also, some hybrid meta-heuristics are capable of obtaining the best solution. Gambardella et al. (1997) solved the QAP with a hybrid ACO algorithm and simple local search called (HAS-QAP). They compared this algorithm with tabu search (TS), reactive TS, hybrid genetic algorithm (GA) and simulated annealing (SA). The comparisons show that the hybrid GA has better performance to solve this problem. Lim et al. (2000) proposed a hybrid GA with a deterministic local search procedure to solve the QAP. Tseng & Liang (2006) proposed a hybrid meta-heuristic algorithm that integrated ACO, GA and local search method, called ANGEL. They showed the ability of ANGEL for obtaining optimal solutions with a 90 % success rate.

As an example of new studies, Tasgetiren et al. (2013) proposed three meta-heuristics to solve the QAP and used an iterated greedy algorithm (IGA), discrete differential evolution (DDE) algorithm and migrating birds' optimization (MBO) algorithm by using the test problem of the QAPLIB (Burkard et al., 1997). The results show better performance of the IGA. (Kaviani et al., 2014) presented a hybrid meta-heuristic based on TS and SA to solve the QAP by using the QAPLIB's test problems.

To the best of our knowledge, this paper is one of comparison studies for analyzing the performance of different meta-heuristics for the QAP. The matter that distinguishes this paper from the other is the comparative performance of local and global search (both EA and SI) meta-heuristic algorithms that consist of the GA (Holland, 1975), SA (Hwang, 1988), particle swarm optimization (PSO) (Kennedy & Eberhat, 1997), hybrid GA-PSO, grey wolf optimizer (GWO) (Mirjalili et al., 2014), harmony search (HS) (Geem et al., 2001). Also, one improvement heuristic algorithm (i.e., 2-Opt) is used to compare with others. Additionally, the PSO, GWO and 2-Opt algorithms are improved to achieve the better comparison toward the other algorithms for evaluation with new metrics. In Section 2, a brief description about the QAP and QAPLIB is presented. The description about algorithms is presented in Section 3. Section 4 shows the applied metrics for evaluation algorithms. In Section 5 the numerical results and analysis are provided and the conclusion and future research are provided in Section 6.

2. Quadratic Assignment Problem (QAP)

The QAP formulation was first presented by Koopmans & Beckmann (1975).

$$\text{Min } z = \sum_{i,j=1} \sum_{p,k=1} f_{ij} d_{kp} x_{ik} x_{jp} \tag{1}$$

s.t.

$$\sum_{i \in n} x_{ij} = 1 \qquad 1 \le j \le n \tag{2}$$

$$\sum_{j \in n} x_{ij} = 1 \qquad 1 \le i \le n \tag{3}$$

$$x_{ij} \in \{0,1\} \qquad 1 \le i, j \le n \tag{4}$$

where $F = [f_{ij}]_{n\times n}$ is the flow matrix between facilities i and j, $D = [d_{kl}]_{n\times n}$ is the distance matrix between locations k and l. By considering the allocation cost of facilities to locations, the problem can be formulated by:

$$\text{Min } z = \sum_{i,j=1} \sum_{p,k=1} f_{ij} d_{kp} x_{ik} x_{jp} + \sum_{i,k\in n} b_{ik} x_{ij} \tag{5}$$

s.t.

$$\text{Constraints (2) to (4)} \tag{6}$$

where $B = [b_{ik}]_{n\times n}$ the cost matrix of allocation facility k to location i and c_{ijkl} is the cost obtained from $f_{ij}\times d_{kl}$.

2.1 Quadratic Assignment Problem Library (QAPLIB)

The QAPLIB was first published in 1991. It is the collection of the test bed for the QAP from different subscribers. According to the website information, it is getting started from Graz University of Technology, then preserved by the University of Pennsylvania. This library consists of 137 test problems from 15 subscriber sources. These test problems cover the real-world as a random test with a size range from 10 to 256. Because of the continuing demand for these test problems, a major updated version was provided by Burkard et al. (1994). The sizes of all test problems selected for this paper are as follows: Scr15, Scr20, Wil50, Wil100, Tho40 and Tho150.

3. Heuristic and Meta-heuristic Algorithms

In this study, heuristics and metaheuristics are used to solve the QAP. Heuristic algorithms are divided into three classes, namely (1) construction, (2) improvement and (3) hybrid algorithms (Heragu, 2008). In the class of the improvement algorithm, the local search heuristic (LSH) based on the 2-Opt algorithm is used in this study. One of the most popular algorithms for categorizing meta-heuristics is based on a search strategy including local search improvement and global search based meta-heuristics. The global search strategy is a population base including evolutionary algorithm (EA) and swarm intelligence (SI) (Blum & Roli, 2003). According to this category, the meta-heuristic algorithms used in this paper include GA, PSO, hybrid GA-PSO, GWO, HS and SA. Also, one improvement local search heuristic algorithm based on 2-Opt is used in order to compare with other algorithms. The PSO, GWO and 2-Opt are improved to achieve the better comparison toward the other algorithms for evaluation. So, the mechanism of these algorithms is shown in the following sub-sections.

3.1 Local search heuristic (LSH)

A 2-Opt algorithm is a simple improvement algorithm and is used as a simple local search algorithm. The 2-Opt and 3-Opt algorithms were first used to solve the traveling salesman problem (TSP) by Deo and Kowalik (2006). In this paper, the LSH algorithm consists of a 2-Opt algorithm with inversion mutation (IVM) operator (Fogel, 1990) of the GA to improve the diversification in the 2-Opt. The procedure of this algorithm for the QAP is shown in Figure 2.

3.2 Meta-heuristic Algorithms

In this subsection, the meta-heuristic algorithms are explained that have different features from the original version. The motivation for the GA is the mechanism of natural selection and natural genetics as first articulated by Holland (1975). This algorithm consists of a family of parallel, randomized-search optimization heuristics. According to the rich literature review of GA, it refers to the reproduction, mutation, crossover, and selection mechanism. In this study, the selected mechanism consists of the meta-ordering crossover operator (MOX) (Asveren & Molitor, 1996) as crossover operator. For a mutation mechanism, insertion mutation (ISM) (Fogel, 1988), IVM and exchange mutation (EM) (Bankhaf 1990) are used. Also, there are many mechanisms for selecting the individual solutions from the population. The roulette wheel selection is chosen to use in the proposed GA.

Kennedy and Eberhat (1997) developed PSO as a parallel evolutionary computation technique. In order to improve the convergence rate of this algorithm (also hybrid GA-PSO), the coefficient ($\vec{c}_2$) and ($\vec{c}_2$) are updated (i.e., decreased) at each iteration that are fixed in each iteration of the original PSO. In general, it has a high probability that PSO falls into the trap of a local optimal solution in various iterations. In order to improve the solutions of PSO, the mutation operators of the GA are added to obtain the local (or personal) and global best solutions. The procedure of the hybrid GA-PSO algorithm is shown in Figure 3.

Harmony search (HS) is a music-inspired algorithm developed by Geem et al. (2001). The aim of this algorithm is to search for a perfect state of harmony in the musician's improvisation process to find the optimal solution in the optimization process.

Grey wolf optimizer (GWO) is a population-based algorithm, which is inspired by grey wolves (Mirjalili et al., 2014). This algorithm is provided based on hierarchy, tracking, encircling, and attacking mimics of prey. According to the hierarchical feature of GWO, the fitness solution considers as the alpha (α). Also, the second and third best solution is named beta (β) and delta (δ) and other candidate solutions are omega (ω). The hunting or optimization provides by α, β and δ wolves. The ω wolves are the follower. In order to obtain the new position of wolves, two random parameters $\vec{r}_1, \vec{r}_2 \in U\,(0,1)$ that used in encircling prey vector are produced for each type of wolves (i.e., α, β and δ) separately. This mechanism causes the better convergence of the best, mean and worst objective functions of this algorithm.

$S = allocation$, Z=*fitness function*
begin (Alorithm)
1. *Initialize. Set* $Z^* = Z$, $S^* = S$
2. **While** *(t<Max iteration)*
3. *Set i=1 and j=i+1*
4. *Exchange i and j*
5. *Calculated* Z'
6. **If** $(Z' < Z)$
7. $Z^* = Z'$, $S^* = S'$
8. **End** *(if)*
9. **If** *(j<num facility)*
10. *j=j+1*
11. **End** *(if)*
12. **If** *(j=num facility & i<num_facility)*
13. *i=i+1*
14. **End** *(if)*
15. **Go to** *3*
16. S = *Inversion mutation* (S^*)
17. **If** *(i=num facility)*
18. **Go to** *20*
19. **End** *(if)*
20. **If** $(S^* \neq S)$
21. $Z^* = Z$, $S^* = S$
22. **Other**
23. **Go to** *1*
24. **End** *(if)*
25. **End** *(while)*
End (Algorithm)

Figure 2: Pseudo-code of the local search heuristic algorithm

begin (Alorithm)
1. **For** *each particle* $i \in 1,...,I$ **do**
2. *Randomly initialize* $\boldsymbol{x}_i$
3. *Randomly intialize* $\boldsymbol{v}_i$ *(or just set* $\boldsymbol{v}_i$ *equal to zero)*
4. *Set* $\boldsymbol{p}_i = \boldsymbol{x}_i$
5. **End** *(for)*
6. **Repeat**
7. **For** *each particle* $i \in 1,...,I$ **do**
8. *Evaluate the fitness of particle i by* $f(\boldsymbol{x}_i)$
9. *Update* $\boldsymbol{p}_i$
10. $\boldsymbol{p}_i'$ = *perfom mutation on* $\boldsymbol{p}_i$
11. **If** $(f(\boldsymbol{p}_i') < f(\boldsymbol{p}_i))$
12. $\boldsymbol{p}_i \leftarrow \boldsymbol{p}_i'$
13. **End** *(if)*
14. *Update* $\hat{\boldsymbol{p}}$
15. $\hat{\boldsymbol{p}}'$ = *perfom mutation on* $\hat{\boldsymbol{p}}$
16. **If** $(f(\hat{\boldsymbol{p}}') < f(\hat{\boldsymbol{p}}))$
17. $\hat{\boldsymbol{p}} \leftarrow \hat{\boldsymbol{p}}'$
18. **End** *(if)*
19. **For** *each dimension j* **do**
20. *Update apply velocity*
21. **End** *(for)*
22. *Update apply position*
23. *Update coefficient* c_1 *and* c_2
24. **End** *(for)*
25. **Until** *some convergence criteria is satisfied*
End (Algorithm)

Figure 3: Pseudo-code of the hybrid GA-PSO algorithm

4. Evaluation Metrics

The meta-heuristic algorithms utilize different strategies for searching in a solution area. It is essential to analyze their performances for different problems. This paper is one of comparative studies, which applies different meta-heuristics for solving the QAP. In order to analyze the comparative advantage of these algorithms, firstly all the parameters of the algorithms should be tuned. In order to tune parameters, first several experiments should be designed, then parameters will be optimized based on that experiments. To do this, the Taguchi method is used for the design of experiment (DOE) with respect to the parameters of the algorithms. The algorithms run 4 times for each experiment, and average output was considered for the test. Then, we use

Minitab 16 statistical software for implanting the Taguchi test. As a result, all of the algorithms in this paper are tuned and optimized by this method. Then because of their stochastic behavior, these algorithms are run several times. There are several indicators to evaluate the common feature of each algorithm. A number of indicators include, rate of efficiency, robustness of computing, rate of convergence, deviation of a solution and the like. In this paper, eight factors are presented that consist of the mean of best, average and worst costs; variance of best, average and worst costs; run time; and the efficiency rate. By taking into account all these factors, the test is implemented in six test problems of the QAPLIB from different sizes (Burkardet al., 1997).

In an analysis of the efficiency rate, the time of each iteration is measured. It is better to measure the time between iterations t and t+1 (λ_{t+1}), because the complexity of the first iteration has a lot of tolerances from the complexity of last iterations. In order to compare the efficiency rate of each algorithm together, choose one of the three formulations as shown below:

$\lambda_{min} = min_s\{\lambda_{s+1}\}$	Minimum number of time\iteration to find new solutions.
$\bar{\lambda} = \left(\sum_{s=1}^{S-1} \lambda_{s+1}\right) \Big/ S$	Mean number of time\iteration to find new solutions.
$\lambda_{max} = max_s\{\lambda_{s+1}\}$	Maximum number of time\iteration to find new solutions.

The algorithm is more robust if the variance of λ_{s+1} is less than other algorithms. In order to compare the robustness of several algorithms, it is better to use the “goodness of fit” test. Each algorithm with the closest value of λ_{t+1} to a uniform distribution between (λ_{min} , λ_{max}) is selected as robustness algorithm.

Another important factor for comparison the performance of meta-heuristic algorithms is a strong convergence condition. One of the contributions of this paper is to measure this factor for each algorithm in a different way. It is measured by calculating the difference between the maximum variation coefficient of n iterations of the algorithms and the minimum of that. When this value is less than δ for k times (where, the value of n, δ and k are tuned), the algorithm will achieve to the strong convergence. The procedure is shown in Figure 4.

```
If (i > n)
   Max coefficient of varition = Max ( √(Variance best (i - n to i )) ) / Mean (Mean (i - n to n))
   Min coefficient of varition = Min ( √(Variance best (i - n to i )) ) / Mean (Mean (i - n to n))
   Gap coefficient of varition = Max coefficient of varition - Min coefficient of varition
   If (Gap coefficient of varition < δ)
      k ← k + 1
   End (if)
End (if)
```

Figure 4: Procedure for evaluating the strong convergence

5. Experimental Results

In this section, the result of eight factors and best objective function are first illustrated for seven algorithms on the test problems from the QAPLIB. All these algorithms are run in MATLAB R2013b software using a computer with the processor of Pentium Dual-Core, 2 Gb RAM, and 64-bit operating system. So, the results for the smallest and biggest test problems are shown in Table 1. In addition to these results, the first most important diagrams are convergence diagrams of the best, worst and average values. These diagrams show the decreasing rate of the variation of the solutions obtained by the algorithms through iterations. The second important factor is the time at which the three diagrams are met. According to the results illustrated in Table 1, the best objective function of SA is better than the others for small and medium sizes; however, the convergence of the objective function of the GA is better than the time. However, the efficiency shows the dispersion in the last iterations for both GA and SA. The dispersion in CPU time of the iterations shows that both algorithms are unstable in the last iterations. In this case, considering the mean of the best, average and worst variances and the efficiency diagram LSH has the best behavior among these algorithms. One of the best local search algorithm for the QAP is 2-Opt and inserting the mutation operator in this algorithm is improved the algorithm in an excellent way. The efficiency rate for the LHS is so good and it shows the significant stability of the algorithm. After LSH, the efficiency rate is shown the stability of the GA as well. The stability is important for the algorithms, because the stability is a factor showing the intelligence of the algorithm. The stable algorithms show the equivalent results during every use of the algorithm.

The run time of PSO is lower than others because the decreasing rate of the PSO algorithm through the iterations is high. However, the best and mean of the best, average and worst objective functions are increased. Since the population of the algorithm is not shown the equivalent behavior through the time, the algorithm is trapped in local optimums easily, and the algorithm binds in stagnation in the feasible area. By adding the mutation operators when obtaining the local and global best solutions in PSO, the best solution is improved.

Table 1: Comparison of results obtained by seven algorithms

Q.M	T.P	GA	PSO	GA-PSO	GWO	HS	SA	LSH
Best Obj.		27953	32465	28523	38639	35024	25570	27964
M.B		28333	32651	30019	38459	35201	26436	27964
M.A		28694	41902	47110	38447	51506	29308	29612.6
M.W		28358	61080	61782	38506	649448	32829	34470.1
V.B	*Scr15*	1302400	6380300	8321700	7504200	122560	2180852	0
V.A		5618100	1794100	1257800	7465600	12.256	6907100	26966.6
V.W		8622400	3259000	25915000	8207200	0	13708727	499990.6
Efficiency		0.097	0.037	0.091	0.019	0.001	0.211	0.02
Time (s)		19.306	7.385	17.691	2.372	0.165	42.025	0.6
Best Obj.		4187055	4713723	4514603	4803499	4803239	4360028	4197255
M.B		4289266	4719800	4581600	4803900	4803400	4494691	4197416.8
M.A		4292088	4885000	4891000	4864300	4901200	4544923	4203400.7
M.W		4292955	4971800	4975500	4887500	5001047	4598950	4210389.9
V.B	*Tho150*	1.5×10^{13}	16366000	1.94×10^{12}	1.65×10^{12}	778870	1.39×10^{10}	18145132.2
V.A		1.6×10^{13}	1.70×10^{12}	1.71×10^{12}	1.71×10^{12}	778871	1.51×10^{10}	73767720.9
V.W		1.7×10^{13}	1.71×10^{12}	1.79×10^{12}	1.72×10^{12}	0	1.68×10^{10}	293261029
Efficiency		0.295	0.165	0.389	0.155	0.005	1.533	0.267
Time		413.437	230.465	544.847	216.894	7.545	305.059	373.082

QM: Quality Measurement; **MB:** Mean of Best cost; **MA:** Mean of Average cost; **MW:** Mean of Worst cost; **VB:** Variance of Best cost; **VA:** Variance of Average cost; **VW:** Variance of Worst cost; **TP:** Test Problem

The HS algorithm has good results for the efficiency and runtime; however, one of the weaknesses in this algorithm is disability of the improvement mechanism in GWO. The convergence of its objective function is better than HS; however, the efficiency rate (or dispersion in its efficiency diagram) shows the disability of the algorithm preserving its stability through the iterations is greater than HS.

The results show that each algorithm has special characteristics and it can be seen that the GA is the best algorithm with respect to the best mean value of the objective function. However, SA has the best objective function for small and medium sizes. Also, by taking into account the efficiency rate and the runtime, LSH has the best behavior among these algorithms. With respect to the convergence rate, the GA shows the better behavior among the presented algorithms.

The results of a strong convergence condition for several runs of the algorithms (with Tho150) are shown in Table 2. In the several runs of the algorithms, SA has a better objective function, but it takes much run time and number of iterations. Also, by comparing the diagram of the strong convergence of the best, worst, and average objective function values and the diagram of the efficiency of GA (Figure 5 and 6) with the diagrams of SA (Figure 7 and 8), GA-PSO (Figure 9 and 10) and LSH (Figure 11 and 12), it can be observed that the strong convergence of GA for best, mean and worst objective function is better than the other algorithms. However, the diagram of the efficiency shows the dispersion in the last iterations for LSH is less than the others.

In comparison of hybrid GA-PSO with PSO (Figure 13 and 14), the results show that the best objective function for the hybrid algorithm is improved; however, the PSO has a better strong convergence for the objective function. Also, the dispersion in iterations of PSO for the efficiency diagram is less than the hybrid algorithm.

Table 2: The results strong convergence

S.C	Best Obj.			Num. of iteration			Run time		
	Max	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*
GA	4175060	4167537.5	4151565	4375	3883.5	2950	606.0399	533.3539	409.0175
PSO	4709245	4678861	4641674	1047	909.25	749	72.2529	63.0459	52.2574
GA-PSO	4172771	4162922	4155533	5484	5059.67	4532	751.8737	684.9693	604.2
GWO	4792310	4777367	4740151	387	367.75	345	28.02158	25.8379	23.6841
HS	4807364	4803414	4793364	551	327.25	202	4.4668	2.8946	1.5650
SA	4123061	4120449.8	4116408	12743	11886	10584	3731.9213	3451.4616	3069.2456
LSH	4177303	4169327	4159696	46	45.5	45	35.37876	32.52807	30.89023

S.C: Strong Convergence.

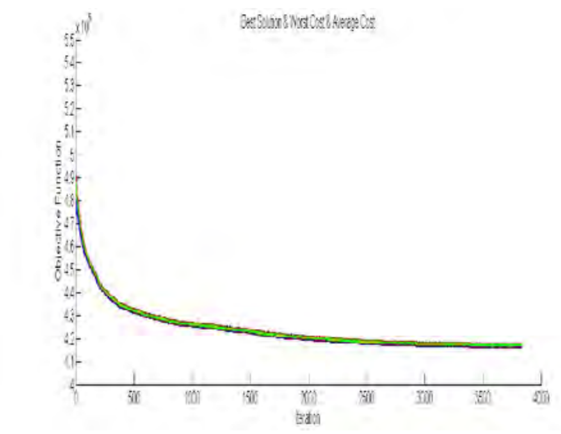

Figure 5: Strong converges rate of the best, average and worst solutions for the GA

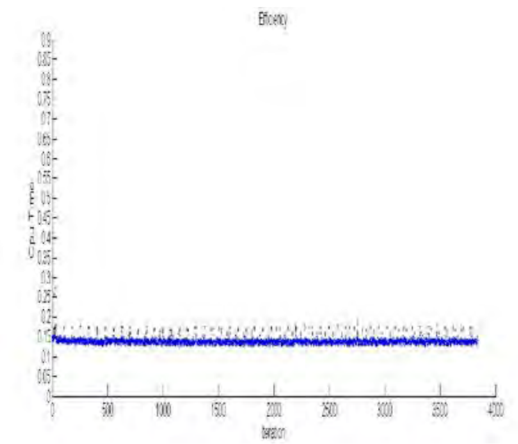

Figure 6: Time efficiency of strong convergence for the GA

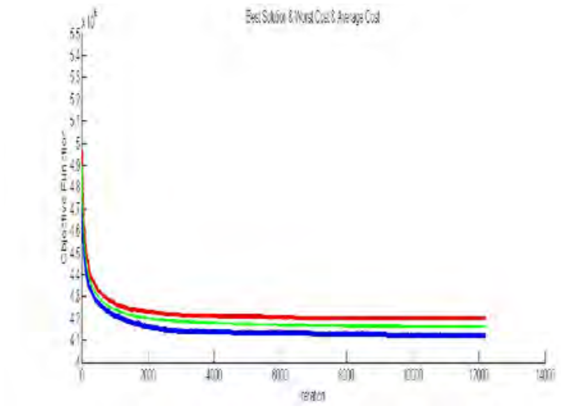

Figure 7: Strong converges rate of the best, average and worst solutions for SA

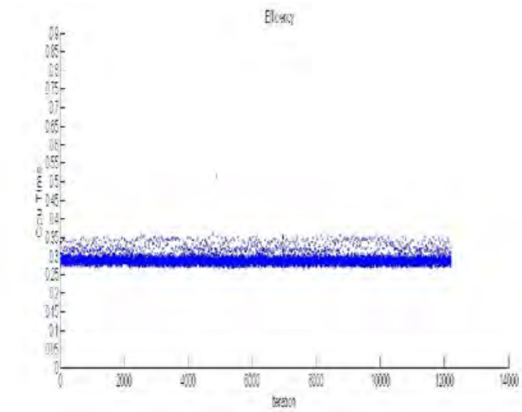

Figure 8: Time efficiency of strong convergence for SA

By comparing the HS (Figure 15 and 16) and GWO (Figure 17 and 18) algorithms, HS has good results for the efficiency and runtime; however, one of the weaknesses in the HS algorithm is its disability in meliorate of the worst value and average value of the algorithm. By the improvement mechanism used in GWO, it can be seen that the strong convergence of the objective function for GWO is better than HS. But, the dispersion in its efficiency diagram of the GWO is shown the disability of the algorithm in preserving its stability through the iterations.

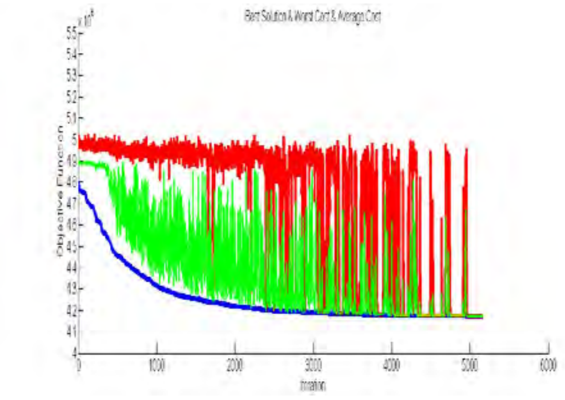

Figure 9: Strong converges rate of Best, average and worst solution for Hybrid GA-PSO

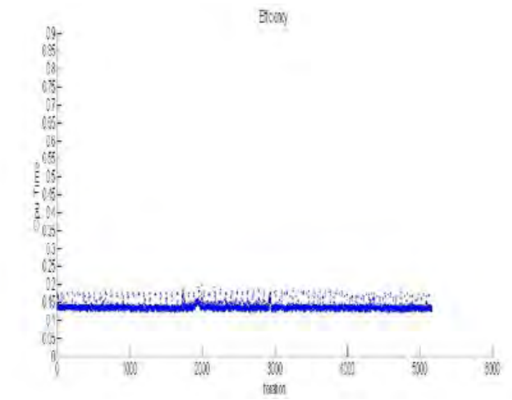

Figure 10: The time efficiency of strong convergence for Hybrid GA-PSO

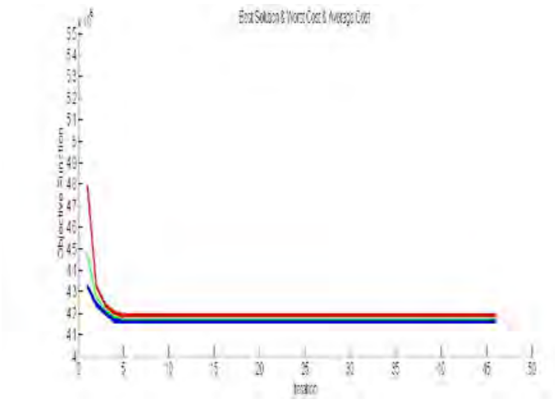

Figure 11: Strong converges rate of the best, average and worst solutions for LSH

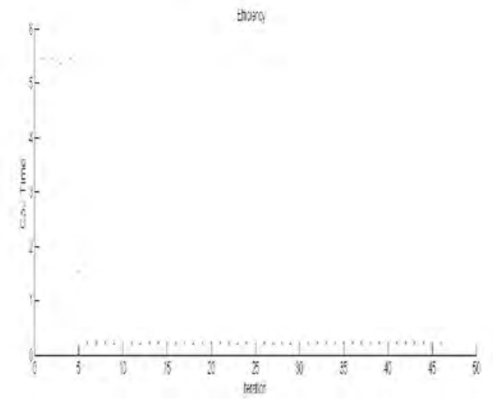

Figure 12: Time efficiency of the strong convergence for LSH

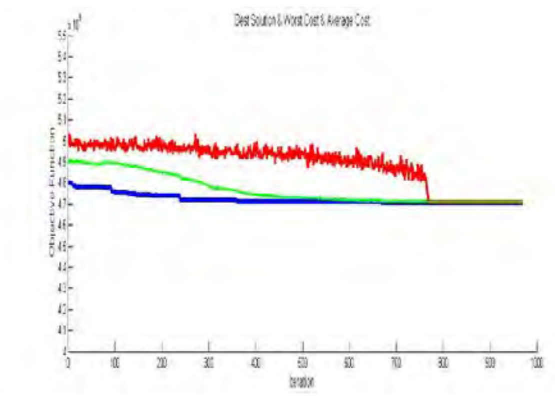

Figure 13: Strong converges rate of the best, average and worst solutions for PSO

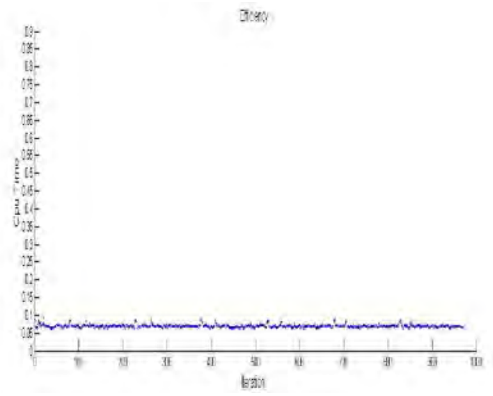

Figure 14: Time efficiency of the strong convergence for PSO

In order to show the trend of the strong convergence of all the algorithms, the results variance of the objective function for 50 initial iterations is shown in Figure 19. Each algorithm that has low variance fluctuation, will converge faster. The convergence rate of the GA from the first iteration is appropriate. Also, GWO and LHS show the good convergence after giving improvement mechanisms. According to the previous result of SA, this algorithm needs to long runtime for reaching the strong convergence. The PSO convergence is not occurring in the initial iterations of this algorithm. It can achieve the strong convergence after a lot of iterations with effect of an improvement mechanism as mentioned above.

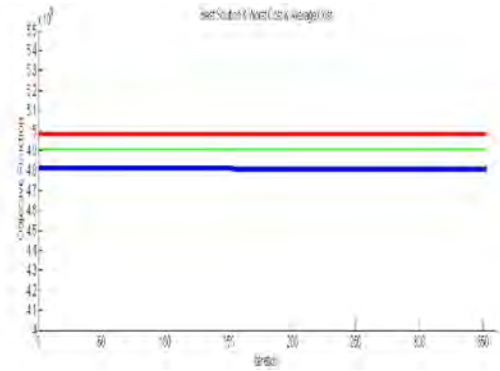

Figure 15: Strong converges rate of the best, average and worst solutions for HS

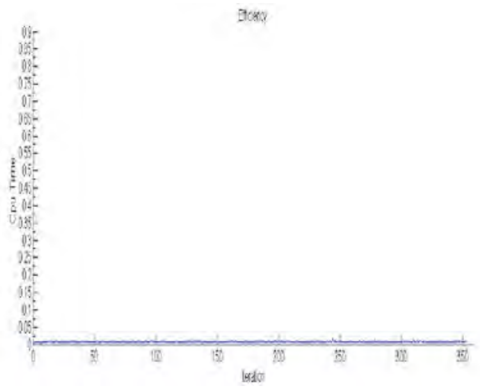

Figure 16: Time efficiency of the strong convergence for HS

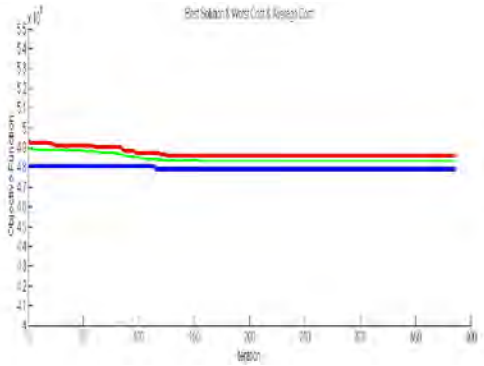

Figure 17: Strong converges rate of the best, average and worst solutions for GWO

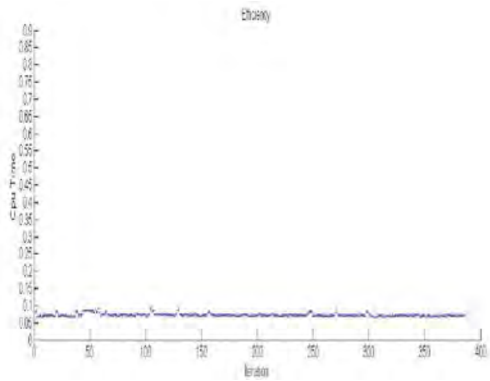

Figure 18: Time efficiency of the strong convergence for GWO

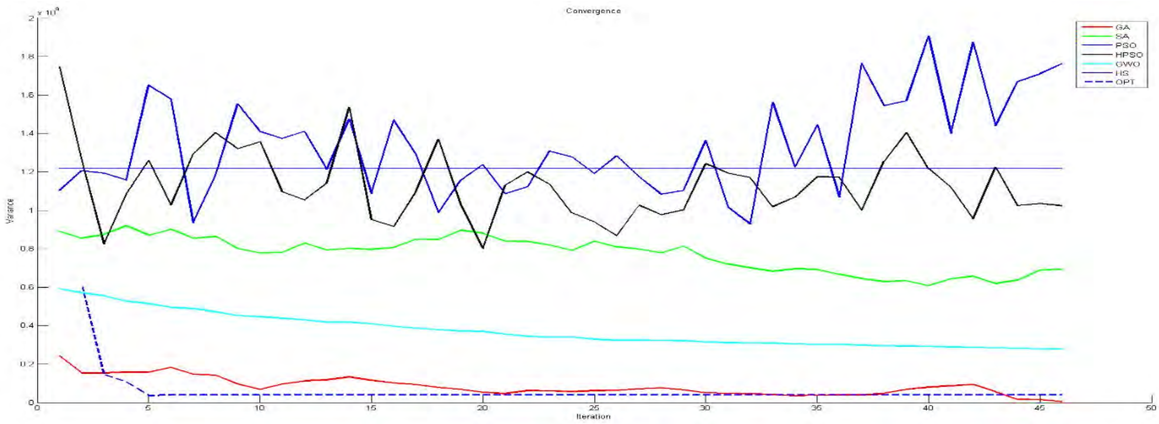

Figure 19: Comparison of the trend of the strong convergence for 50 initial iterations of all algorithms

Conclusion

In this research, we first implemented seven algorithms on the QAP and improved the mechanism of three of them (i.e., PSO, GWO and 2-Opt). Then, we presented a new framework for comparing the algorithms. Additionally, we presented eight factors that show the comparative advantage of each algorithm. By taking into account these factors, the test was implemented in six test problems. Furthermore, we used a new mechanism for evaluating the strong convergence condition in these algorithms. With respect to this framework, we can investigate the advantages of the algorithms in order to design a new algorithm using all excellent specifications of these algorithms. Simply, this new algorithm can be developed by the hybrid process of these algorithms.

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Statistical estimation and test of hypothesis with a Weibull distribution: applications to industrial lifetime data

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Weibull distribution is extremely important in the field of reliability and life testing. The major problem in the way of using this distribution is the difficulty in estimating its parameters. The well-known maximum likelihood method can be used but it involves a set of nonlinear equations that do not provide estimates (MLE) in analytically closed form. Numerically iterative solutions are available but they are riddled with many problems. Particularly, if the sample used in the estimation is contaminated or contains outliers in it then the iterations with likelihood equations are often non-converging or may be converging to a wrong value (e.g., local maxima). To alleviate these difficulties, we use the method of modified maximum likelihood where the likelihood equations are derived by expressing the intractable non-linear likelihood equations in terms of standardized ordered variates and replacing the intractable terms by their linear approximation obtained from the first two terms of a Taylor series expansion about the quantiles of the distribution. These estimates (MMLE) are obtained in closed form and they are equivalent to the maximum likelihood estimates, asymptotically. Even in small samples they are found to be approximately the same as maximum likelihood estimates that are obtained iteratively. Here, we derive the MMLE for the parameters of a Weibull distribution and through simulation we show that the estimates are unbiased and efficient in the sense of attaining the Cramer-Rao's minimum variance bound that is derived for all unbiased estimators. It is also demonstrated that these estimates are robust to plausible deviation from an assumed model. Furthermore, they are also found robust to many data anomalies such as contamination, mixtures, and outliers. We also propose the test of hypothesis for the relevant parameters and simulate the size and power of the tests. We also establish the robustness of these tests under various situations. In order to demonstrate the usability and applicability of the MML method we provide some real life examples related with reliability and hazard estimation and testing in engineering systems.

Key Words: Weibull distribution; maximum likelihood estimates; modified maximum likelihood estimates; robustness; outliers; lifetime data.

Cooperation Networks Types and Intensity: Descriptive Analysis of Turkish SMEs

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Abstract

Nowadays, firms' capabilities are not only determined by internal factors, but also depends on firms' collaboration with external actors, especially for small and medium size enterprises. Cooperation with research organizations, public support institutions, intermediary organizations and other firms as external actors play an important role to gain competitive advantage. Cooperation networks were classified into four groups as: research organizations, public support institutions, intermediary organizations and other firms in accordance with the literature. The aim of this study is to show a general picture of cooperation networks intensity of SMEs in Turkey. For this purpose, a web-based survey was prepared with explanatory information of the companies to collect data. Overall, 450 questionnaires were returned, of which 366 were considered valid in accordance with sampling. Some descriptive statistics were obtained to see a general picture of cooperation networks intensity. The type and degree of cooperation networks were also analyzed in order to ask the question of this research. The results show that SMEs have the strongest cooperation with their customers while the cooperation with research centers and institutes is the lowest. Furthermore, in terms of cooperation groups, the degree of cooperation ranged as firms, intermediary organizations, public support institutions, and research organizations, respectively. These results obtained from analyses make valuable contributions to managers of SMEs and all stakeholders, policy maker and law maker to scrutinize and revise their policies and strategies in order to increase effective cooperation among actors.

Keywords

Innovation capability, measurement models, conceptual models, confusion

1. Introduction

Cooperation between firms has been more important in competitive industry world. Firms' capabilities are not only determined by internal factors, but also depends on the nature a firm's interaction with external actors. Cooperation with research organizations, public support institutions, intermediary organizations and other firms as external actors play an important role in improving firm own capabilities, especially for small and medium size enterprises. SMEs have behavioral advantages and resource disadvantages in bringing innovation about and SMEs, in general have a short term focus (Bos-Brouwers, 2010). Some of the biggest obstacles in front of SMEs in Turkey are difficulties to meet the financial requirements, managerial problems and lack of resources (Kaya and Alpkan, 2012). Furthermore, effective public support structures and intermediary organizations can play an important role in facilitating innovative process (Hofman & Bruijn, 2010) and stakeholders have an influence on the strategic change in SMEs. In order to overcome these difficulties they need to get support from government and make collaboration with external actors. The cooperation networks for innovation is one of the most recent issues in engineering management field. Cooperation networks were classified into four groups as: research organizations, public support institutions, intermediary organizations and other firms based on (Xeng et al. 2010)'s study in accordance with the literature. Research organizations consist of universities, research centers and institutes, community colleges and academies. Public support institutions include the scientific and technological research council of Turkey (TUBITAK), small and medium enterprises development organization

(KOSGEB), development agencies, and other ministries. Intermediary organizations contain commercial and industry associations, commercial labs, service providers, non-governmental organizations, and venture capital organizations. Other firms also comprise customers, suppliers, and rivals. There are different approaches in defining SMEs by different institutions and association in Turkey (Kaya and Alpkan, 2012) and it had been updated by public authorities for several times. The current definition of SMEs in Turkey incorporates companies that employs between 1 and 250 staff and its financial balance sheet or annual net sales revenue does not exceed 40 million YTL. SMEs are classified into 3 groups as: micro, small and medium size according to the number of employee and value of financial balance sheet or annual net sales revenue. Micro size companies have 1-9 employees and 1 million YTL financial balance sheet or annual net sales revenue; small size companies have 10-49 employees and 8 million YTL financial balance sheet or annual net sales revenue; medium size companies have 50-249 employees and 40 million YTL financial balance sheet or annual net sales revenue (KSEP, 2015). Moreover, SMEs constitutes majority of the workforce involved in Turkey hence they play a particularly important role in the Turkish economy. The government authorities have also carried out a variety of programmes to support these enterprises for many years (OECD, 2004). We took small and medium size companies into consideration in this study because it is very hard to reach the micro size companies. Our main purpose in this study is to show a general picture of cooperation networks intensity of SMEs in Turkey. The remaining sections of this paper are organized as follows. Section 2 presents data collection and Section.3 mentions data analysis and results. Conclusion and further research are presented in Section 4.

2. Data Collection

Data collection phase was conducted via a web based survey. In order to overcome the difficulties of data collection, supports from Istanbul Technical University- scientific research project center and Kosgeb were received. A web-based survey was prepared with explanatory information of the companies (year of establishment, sector, number of employee, and position of respondent) to collect data by using stratified random sampling method. An e-mail invitation that included a brief introduction and a link to the web questionnaire was sent to a senior manager by using computer aided telephone interview method to encourage them to participate. A number of screening questions were used to ensure only qualified respondents participated in the survey. The five-point Likert scales that ranged from “strongly disagree” to “strongly agree” was used to evaluate the questions. Overall, 450 questionnaires were returned, of which 366 were considered valid in accordance with sampling. Some descriptive statistics were obtained to see a general picture of data and cooperation networks.

3. Data Analysis and Results

In this phase, data was analyzed by IBM-SPSS 22 software. First, the distributions of SMEs were given in Table 1 and Figure 1 in terms of sector, region and firm size. Sectors are service, manufacturing, construction and trade while scale is divided as small and medium size in accordance with KOSGEB classification. At the same time, Turkey has 6 different regions according to KOSGEB classification as well. This classification was also used in stratified random sampling method. In Table 1, firms were given in terms of sector, region and firm size together. It indicates more than half of the companies are established in Region 1 and Region 2. At the same time, some interaction cluster has 1 sample while a medium construction firm in Region 5 was not found.

Table 1: The distribution of firms (sector, region and firm size)

Sectors	Service		Manufacturing		Construction		Trade		Total
Region/Size	Small	Medium	Small	Medium	Small	Medium	Small	Medium	
Region 1	39	16	28	22	16	7	26	14	168
Region 2	12	1	18	5	6	5	12	6	65
Region 3	11	4	6	3	6	2	5	7	44
Region 4	13	0	7	5	6	2	6	2	41
Region 5	11	1	8	1	1		6	1	29
Region 6	4	1	3	2	1	2	5	1	19
Total	90	23	70	38	36	18	60	31	366

At the same time, the distribution of sectors in terms of firm size can be seen in Fig. 1. Sectors range as service, manufacturing, trade and construction for small enterprises while range as manufacturing, trade, service and construction for medium size companies according to the number of companies. Furthermore, the oldest firm is 86 while the average age is 19 and the values of median and mod both are 16 by taking the establishment year into consideration.

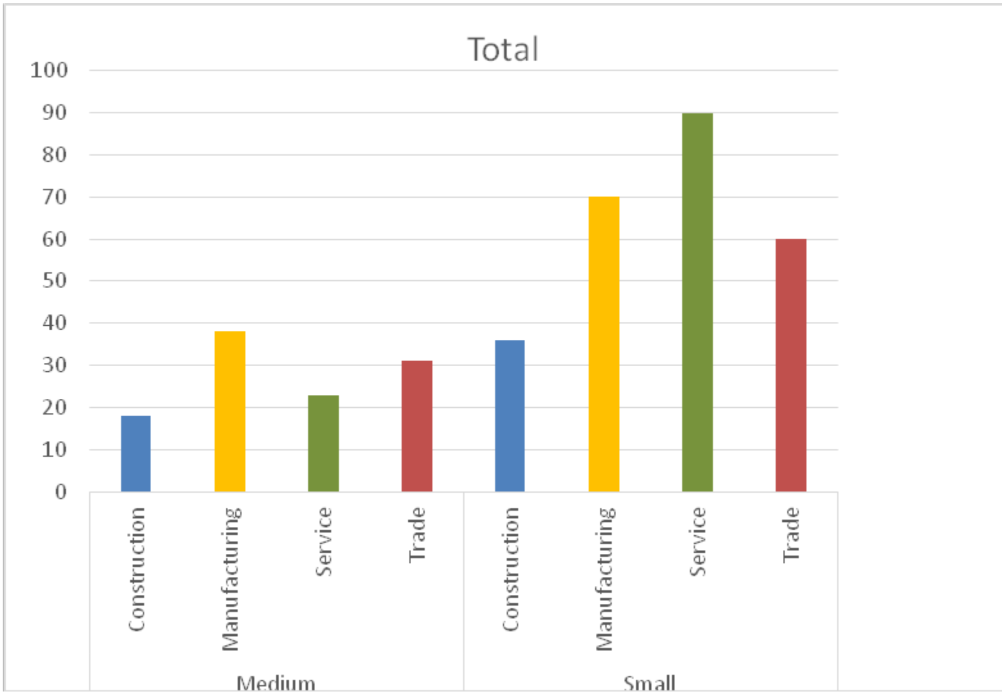

Figure 1: The distribution of sectors in terms of firm size

Second, the intensity of cooperation networks were analyzed in order to ask the question of this research. The results show that SMEs had the strongest cooperation with their customers while the cooperation with research centers and institutes was the lowest. Furthermore, in terms of cooperation groups, the degree of cooperation ranged as firms, intermediary organizations, public support institutions, and research organizations, respectively. This score was calculated under equivalent assumption and average method. The number of cooperation and intensity for each cooperation types and groups were presented in subsequent tables, respectively. The strongest intensity was customer with (4,52) and the lowest one was research centers and institutes with (2,67). The general average was 3,45 and this was below the expected value (3,50). If firms are excepted, the value would decrease to the level of 2,94 and moved away from expected value. When we look at the intensity as cooperation groups, they ranged respectively as: firms with (4,06), intermediary organizations with (3,12), public support institutions with (2,90) and research organizations with (2,71). It was observed that the cooperation intensity of public support institutions, and research organizations are lower than firms and intermediary organizations. On the other hand, in terms of the distribution among research organizations, Table 2 shows that %72% of SMEs have no collaboration with universities.

Table 2: The intensity of research organizations

	Universities	Research Centers and Institutes	Community Colleges and Academies	Average
No Cooperation	263	284	267	271
Low Level	57	43	44	48
Medium Level	26	23	39	29
High Level	16	16	9	14
Very High level	4	0	7	4
Degree of Cooperation	2,68	2,67	2,79	2,71

This ratio was observed for research centers and institutes as 78% and for community colleges and academies as 73%. Very high and high level cooperation with universities together was 5%, with research centers and institutes was 4%, with community colleges and academies was 4%. In this cooperation type, although the intensity of cooperation was close to each other, of research centers and institutes was lesser than other types. Similarly, in terms of cooperation with public support institutions, %81 of SMEs had no collaboration with Development Agencies, 77% with TUBITAK, 74% with Other Ministries and 59% with KOSGEB. At the same time, while the highest intensity was occurred with Other Ministries, the lowest intensity was observed with TUBITAK and Development Agencies.

Table 3: The intensity of public support institutions

	TUBITAK	KOSGEB	Development Agencies	Other Ministries	Average
No Cooperation	280	215	297	272	266
Low Level	44	62	37	31	44
Medium Level	28	48	20	33	32
High Level	9	27	6	17	15
Very High level	5	14	6	13	10
Degree of Cooperation	2,71	2,95	2,72	3,13	2,90

Moreover, Table 4 shows that the collaboration among firms was very intensive. While 88% of SMEs had very high and high level cooperation with customer and 74% with suppliers, cooperation with rivals with 30% was relatively lower than others. Furthermore, approximately half of cooperation with rivals incorporated medium and low level cooperation.

Table 4: The intensity of firms

	Customers	Suppliers	Rivals	Average
No Cooperation	4	19	81	35
Low Level	5	6	63	25
Medium Level	33	67	113	71
High Level	92	115	81	96
Very High level	232	159	28	140
Degree of Cooperation	4,52	4,23	3,26	4,06

Finally, when we look at the cooperation with intermediary organization, as can be seen in Table 5, 81% of SMEs had no collaboration with Venture Capital Organizations. This ratio was occurred for NGOs as 72%, for Technology Intermediaries as 62% and for Commercial and Industry Association as 45%. Moreover, very high and high level cooperation with Commercial and Industry Association together was 18%, with NGOs was 10%, with technology Intermediaries was 9% and also with Venture Capital Organizations was 4%. This ratios indicate that while the highest intensity was observed with Commercial and Industry Association, the lowest intensity was occurred with Venture Capital Organizations.

Table 5: The intensity of intermediary organizations

	Technology Intermediaries	Venture Capital Organizations	Commercial and Industry Association	Venture Capital Organizations	Average
No Cooperation	227	262	164	295	237
Low Level	48	35	43	30	39
Medium Level	56	34	90	27	52
High Level	19	21	42	8	23
Very High level	16	14	27	6	16
Degree of Cooperation	3,02	3,13	3,26	2,86	3,12

4. Conclusion and Further Research

Cooperation with research organizations, public support institutions, intermediary organizations and other firms play a crucial role to improve capabilities of companies, especially for small and medium size enterprises. At the same time, SMEs are important for Turkish economy by presenting majority of the workforce involved in Turkey and Turkish government support and subsidize SMEs by presenting variety of programmes. The aim of this study to take a general picture the type and intensity of cooperation networks of SMEs in Turkey. For that reason, a web-based survey was prepared to collect data and 366 industry data in order to obtain descriptive statistics about cooperation networks intensity. The results show that SMEs have the strongest cooperation with their customers while the cooperation with research centers and institutes is the lowest. Furthermore, in terms of cooperation groups, the degree of cooperation ranged as firms, intermediary organizations, public support institutions, and research organizations, respectively. These results obtained from analyses make valuable contributions to managers of SMEs and all stakeholders, policy maker and law maker to scrutinize and revise their policies and strategies in order to increase effective cooperation among actors. These results also provide motivation to make detail analyses to explore the reasons why majority of SMEs do not or not be able to make collaboration with external actors. On the other hand, these results could be compared the large scale companies to see the differences and similarities. Furthermore, researchers could ask whether there are any differences between intensity of cooperation in terms of sector and region that companies operate in, and firm age by conducting large sample.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A Tri-Level *r*-Interdiction Median Model for a Hierarchical Facilities Location Problem

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Abstract

By losing critical facilities by terrorist attacks or natural disasters, the system may be at risk. Interdiction models with enhanced security and fortifying critical infrastructure help to the stability and efficiency of services during intentional attacks. The aim of these models are to investigate the vulnerability of the system and anticipated damage of clever attacks by attackers in the worst possible scenarios. In this paper, a tri-level programming model is developed to locate the hierarchical facilities exposed to the disorder. The tri-level model is suggested in the form of the defender-attacker-defender. In this model based on a game theory approach, a defender is to locate a facility as the original decision maker in the level one. For each of the location strategy adopted by a defender, the attacker is to maximize the services cost by disrupting in a system in the level two. The attacker plans its aggressive strategy by considering the next reaction of a defender with minimizing the disorder costs under a leader-follower game. The defender reactions includes the way to assign customers to the facility and fortification them in the third level of the model. Because the proposed model is NP-hard to optimally solve in a reasonable time, we propose two hybrid meta-heuristic algorithms based on tabu search (TS) and simulated annealing (SA) for the level one and exact methods for the levels two and three. The obtained results implies that the effect of correct locating strategies to reduce the facility costs exposed to disorder.

Keywords

Hierarchical facility location, *r*-Median interdiction problem, three-level programming, probabilistic fortification, meta-heuristic algorithms.

1. Introduction

Protection of critical infrastructure is important in services systems. Critical infrastructure can include transportation linkage (e.g., bridges, tunnels and rail) facilities (e.g., port terminals, production facilities, warehouses, operation centers, emergency response facilities and hospitals), critical stockpiles (e.g., vaccine, drugs and food), key personnel (e.g., water system operators) and land marks that may contribute to the loss of well-being (Church and Scaparra, 2007). Increase of quantity and quality of intentional disruptions in recent years, increased more attention to this area. Unfortunately, today terrorists because of the ease of access to information and using modern technology, able to identify the best possible methods to maximize damage. For example, in the 2003 Istanbul bombings by al-Qaeda suicide bombers in Great Britain and the Consulate General Staff and Great Britain Bank, 57 and 700 civilians were killed and wounded, respectively. Attacks on a telecommunication tower in Afghanistan in 2008, an ambulance station in Northern Ireland (Aksen et al., 2010) are typical examples, in which terrorists/attackers plan to disrupt services. Furthermore, natural disasters (e.g., floods, hurricanes, tornadoes and earthquakes) are the major threats, which leads to disruption of critical facilities. Therefore, identification of critical infrastructure and analyses options for fortifying and strengthening their safety is an important issue. The roots of protection planning can be traced back to military defense applications, in which enemy attacks are analyzed, called interdiction models. Interdiction models with enhanced security and fortifying critical infrastructure help to the stability and efficiency of services during the intentional attacks. The aim of these models are to investigate the vulnerability of the system and anticipated damage of clever attacks by attackers in the worst possible scenarios. Interdiction models are used in detection communication paths or sensitive networks. Typically, disruption in these systems are considered in two ways, namely interdiction on nodes and edges. The models presented in the area of node interdiction are classified in two categories *r*-interdiction median (RIM) and *r*-interdiction covering (RIC) problems (Church et al., 2004).

A tri-level mathematical model as a defender-attacker-defender is to locate a hierarchical facility exposed to the disorder. In this model based on a game theory approach, a defender is to locate facility as the original decision maker in the level one. For each location strategy adopted by a defender, an attacker is to maximize services cost by disrupting in a system in the level two. An attacker plans its aggressive strategy considering the next reaction of a defender in minimizing disorder costs under a leader-follower game. The defender reactions includes the way to assign customers to the facility and fortification them in the third level of the model.

Given that the proposed model is NP-hard to solve in a reasonable time, we use two hybrid algorithm based on tabu search and simulated annealing for the level one and exact methods for the levels two and three. The obtained results implies that the effect of correct locating strategies to reduce facility costs exposed to a disorder.

The rest of the paper is organized as follows. In Section 2, we review the previous studies. In Section 3, the problem definition and mathematical model are presented. The proposed solution methods are explained in Section 4. Sections 5 and 6 handle the computational experiments to show the efficiency of the model. Finally, the paper concludes in Section 7.

2. Literature review

The first published study of supply or emergency facility interdiction in a service network is based on Church et al., (2004). Disruption in these systems are considered in two ways, namely interdictions on nodes and edges. Additionally, the models presented in the node interdiction area are classified in two categories, namely *r*-interdiction median (RIM) and *r*-interdiction covering (RIC) problems. The subsequent study is related to Brown et al. [6], which serves as a comprehensive interdiction to bi-level and tri-level interdiction problems involving an attacker and a defender. Moreover, Losada et al., (2012) considered an uncertainly interdiction problem with intensity levels of interdiction for RIM problems. Furthermore, Liberatore et al., (2012) provided a tri-level problem at protection of facilities. In their model, the first, second and third levels are concerned to fortification, interdiction and reduction on the total costs of the defender, respectively. They proposed an exact solution algorithm, which use a tree-search procedure to identify which facilities to be protected. Similarly, Alguacil et al., (2014) presented a tri-level programming model with the defender-attacker-defender for the pathology of electrical power networks against possible attacks. Also, for the first time, the concept of partial interdiction outsourcing demands after the interdiction was introduced by Aksen et al., (2014).

In the light of the fortification concept, Church and Scaparra (2007) obtained the IMF problem and combined it with RIM models. According to this fortification model, other studies were presented by adding new hypotheses to the given problem; for instance, the facility capacity (Scaparra and Church, 2010), security budget constraint (Aksen et al., 2010), random number of possible losses (Liberatore et al., 2011; Liberatore et al., 2012), and propagation of disturbances in a wide area. Then, Zhu et al. (2013) offered an *r*-interdiction median problem with probable fortification. Also, Aksen et al, (2013) considered fortification in their paper.

Aksen et al. (2013) first presented a paper on the issue of a bi-level location problem, in which fortification and interdiction were considered and formulated. The most significant innovation of this study is to locate facilities by simultaneously considering two scenarios before and after the interdiction. After that, Medal et al. (2014) offered a generalization of a *p*-center problem aimed at minimizing the maximum distance from a demand point to the *r*-th nearest facility location. Then, Medal et al. (2014) offered a generalization of a *p*-center problem aimed at minimizing the maximum distance from a demand point to the *r*-th nearest facility location.

Additionally, Zhang et al. (2015) explored the partial interdiction median problem for multi-sourcing supply systems (PIM-MS), which has three characteristics: (1) limited capacity for each facility, (2) partial interdiction, and (3) a multi-sourcing delivery strategy for supply systems. They formulated their model as a bi-level programming model. Finally, Aliakbarian et al. (2015) offered a bi-level formulation of the *r*-interdiction median problem with fortification for critical hierarchical facilities.

There is a gap in considering the problem from the perspective of the attacker and defender simultaneously.

Furthermore, most of the existing studies assumed that all facilities are in a one level and the models usually are the bi-level one. In order to fill these gaps, this paper contributes to the literature in the following ways:

- Developing a tri-level integer programming model to minimize the total fixed charge of the facility and minimize the total cost of the current facilities established after interdiction.
- Considering two type of hierarchical facilities with nesting features.
- Using an approach to improve costs systems vulnerable to disturbance.
- Considering the possibility of outsourcing for demands.
- Considering the possibility of fortification for defender's facilities.
- Developing two meta-heuristic algorithms to solve large-sized instances.

3. Problem description and mathematical programming

3.1. Tri-level *r*-interdiction median problem for hierarchical facilities (THFRIM)

It is assumed that a general supply/life system consists of several facilities and demand nodes that receive service or goods from their nearest facility sites. A limited resource budget is given to protect critical facilities in the system to prepare for the destructive attacks or natural disasters. Locating the facility is due to the fixed charge facilities and the costs of the current system (Level 1). The problem is modeled as a Stackelberg game between intelligent attacker (Level 2) and a defender (Level 3). A typical objective of the attacker (i.e., follower) is to identify the most critical facilities to interdiction and make the most disruptive attack. The objective defender (i.e., leader) is responsible for satisfying the demand of all customers while minimizing the total transportation and outsourcing costs. The related assumption, parameters and decision variables are given below:

(i). Flow pattern: In this paper, a flow pattern is multi-flow (Sahin et al., 2007).

(ii). Service varieties: A system is classified as nested or non-nested according to the service availability at the levels of hierarchy. In a nested hierarchy, a higher-level facility provides all the services provided by a lower level facility and at least one additional service. We assume that the facilities are nested hierarchy.

(iii). To estimate worst-case losses, we assume that the attacker has complete information regarding the components of the system, including the position of each node and fortified facilities.

(iv). The distribution of defensive resources is determined before interdiction and does not change during the attack.

Index Sets

I	Set of demands nodes (customers), $i \in I$
J	Set of potential sites for construction of the type 1 (level 1) service facility, $j \in J$
K	Set of potential sites construction of the type 2 (level 2) service facilities, $k \in K$

Parameters

a_i	Demand of customer *i*
β_i	Percentage of population *i* that needs to particular service of level 2,
$d_{ij}^{(1)}$	Distance between customer *i* and facility type 1 at site *j*
$d_{ik}^{(2)}$	Distance between customer *i* and facility type 2 at site *k*
$d_{jk}^{(3)}$	Distance between the *j*-th facility type 1 and the *k*-th facility type 2
$c_j^{(1)}$	Capacity of the *j*-th facility type 1
$c_k^{(2)}$	Capacity of the *k*-th facility type 2
B_{att}	Maximum number of facilities that attacker can interdict (attacker power)
$b^{(1)}$	Maximum number of facility type 1 that attacker can interdict
$b^{(2)}$	Maximum number of facility type 2 that attacker can interdict
B_{def}	Maximum number of facilities that defender can fortify (defensive power)
$p^{(1)}$	Maximum number of facility type 1 that defender can fortify

$p^{(2)}$	Maximum number of facility type 2 that defender can fortify
$CS_{(1)}$	Unit shipment cost of demand per unit distance for service type 1
$CS_{(2)}$	Unit shipment cost of demand per unit distance for service type 2
$CO^{(1)}$	Unit outsourcing cost of demand for service type 1 (independent of distance)
$CO^{(2)}$	Unit outsourcing cost of demand for service type 2 (independent of distance)
$f_j^{(1)}$	Fixed cost of construction of facility type 1 at site *j*
$f_k^{(2)}$	Fixed cost of construction of facility type 2 at site *k*

Decision variables

$Y_j^{(1)}$	If customer *i* assigned to facility type 1 at site *j* is 1; otherwise it is 0
W_{ik}	If customer *i* assigned to facility type 2 at site *k* is 1; otherwise it is 0
V_{jk}	If a customer of particular service in the *j*-th facility type 1 assigned to the *k*-th facility type 2 is 1; otherwise it is 0
$S_j^{(1)}$	If a facility type 1 located at site *j* interdicted by an attacker is 1; otherwise it is 0
$S_k^{(2)}$	If a facility type 2 located at site *j* interdicted by an attacker is 1; otherwise it is 0
$Y_j^{(1)}$	If a facility type 1 located at site *j* fortified by a defender is 1; otherwise it is 0
$Y_k^{(2)}$	If a facility type 2 located at site *j* fortified by a defender is 1; otherwise it is 0
$X_j^{(1)}$	If facility type 1 located at site *j* is 1; otherwise it is 0
$X_k^{(2)}$	If facility type 2 located at site *j* is 1; otherwise it is 0

3.2. Mathematical Programming Model

$$Z_1 = \min_x \left(z_2 + \sum_{j \in J} f_j^{(1)}.X_j^{(1)} + \sum_{k \in K} f_k^{(2)}.X_k^{(2)}\right) \tag{1}$$

s.t. (2)

$$\sum_{j \in J} c_j^{(1)}.X_j^{(1)} + \sum_{k \in K} c_k^{(2)}.x_k^{(2)} \geq \sum_{i \in I} a_i$$

$$\sum_{k \in K} c_k^{(2)}.X_k^{(2)} \geq \sum_{i \in I} \beta_i .a_i \tag{3}$$

$$X_j^{(1)} \in \{0,1\} \qquad ;\forall j \in J \tag{4}$$

$$X_k^{(2)} \in \{0,1\} \qquad ;\forall k \in K \tag{5}$$

$$Z_2 = \max_S Z_{att}(S) \tag{6}$$

$$\text{s.t} \sum_{j \in J} b^{(1)}.S_j^{(1)} + \sum_{k \in K} b^{(2)}.S_k^{(2)} \leq B_{att} \tag{7}$$

$$0 \leq S_j^{(1)} \leq X_j^{(1)} \qquad ;\forall j \in J \tag{8}$$

$$0 \leq S_k^{(2)} \leq X_k^{(2)} \qquad ;\forall k \in K \tag{9}$$

$$S_j^{(1)} \in \{0,1\} \qquad ;\forall j \in J \tag{10}$$

$$S_k^{(2)} \in \{0,1\} \qquad ;\forall k \in K \tag{11}$$

$$\begin{aligned} Z_{att}(S) = \min_{U,W,Y,Y} \Big(& CS_1 \times \sum_{j \in J}\sum_{i \in J} a_i .d_{ij}^{(1)}.U_{ij} + CS_2 \times \sum_{k \in K}\sum_{j \in J}\sum_{i \in I} \beta_i .a_i .d_{jk}^{(3)} V_{jk} \\ & + CS_1 \times \sum_{k \in K}\sum_{i \in I}(1-\beta_i).a_i .d_{ik}^{(2)} W_{ik} + CS_2 \times \sum_{k \in k}\sum_{i \in I} \beta_i .a_i .d_{ik}^{(2)} W_{ik} + CO^{(1)} \\ & \times (\sum_{i \in I}(1-\beta_i).a_i .(1-(\sum_{j \in J} U_{ij} + \sum_{k \in K} W_{ik}))) + CO^{(2)} \times (\sum_{i \in I} \beta_i .a_i .(1-(\sum_{j \in J} U_{ij} \end{aligned} \tag{12}$$

$$+\sum_{k\in K} W_{ik}))) + CO^{(2)} \times (\sum_{j\in J}\sum_{i\in I} \beta_i .a_i .U_{ij} .(1-\sum_{k\in K} V_{jk})))$$

s.t $\sum_{j\in J} U_{ij} + \sum_{k\in K} W_{ik} \le 1 \qquad ;\forall i \in I$ (13)

$\sum_{k\in K} V_{jk} \le 1 \qquad ;\forall j \in J$ (14)

$\sum_{j\in J} p^{(1)} Y_j^{(1)} + \sum_{k\in K} p^{(2)} Y_k^{(2)} \le B_{Def}$ (15)

$\sum_{j\in J} a_i .U_{ij} \le c_j^{(1)}.(1-S_j^{(1)}.(1-Y_j^{(1)})).X_j^{(1)} \qquad ;\forall j \in J$ (16)

$\sum_{i\in I} a_i W_{ik} + \sum_{j\in J}\sum_{i\in I} \beta_i .a_i .U_{ij} V_{jk} \le c_k^{(2)}.(1-S_k^{(2)}.(1-Y_k^{(2)})).X_k^{(2)} \qquad ;\forall k \in K$ (17)

$U_{ij} \in \{0,1\} \qquad ;\forall i \in I, j \in J$ (18)

$W_{ik} \in \{0,1\} \qquad ;\forall i \in I, k \in K$ (19)

$V_{jk} \in \{0,1\} \qquad ;\forall j \in J, k \in K$ (20)

$Y_j^{(1)} \in \{0,1\} \qquad ;\forall i \in I$ (21)

$Y_k^{(2)} \in \{0,1\} \qquad ;\forall k \in K$ (22)

New slack variable $W_{ijk}^{'}$ for the linear third-level of the model is defined as follows:

$$U_{ij} + V_{jk} \ge 2W'_{ijk} \tag{23}$$

$$W'_{ijk} \in \{0,1\} \tag{24}$$

In the above formulation, Eqs. (1) to (5) represent the level 1, Eqs. (6) to (11) represent the level 2 and EQs. (12) to (22) represent the level 3 of a defender-attacker-defender's model. The objective function of Eq. (1) consists of two parts. The first part is to minimize the total fixed charge of the facility and the second part is to minimize the total cost of current facilities established after interdiction**.** Constraint (2) ensures that the total capacity of the facility is established (types 1 and 2) more than the demands population area. Constraint (3) ensures that the total capacity of the type 2 facility is established more than percentage of the population area that need to particular service of the level 2. The objective function of the second level focuses to maximize the objective function of the third level (i.e., Expression 6). Constraint (7) shows the maximum attacker power used variables $S_j^{(1)}$ and $S_k^{(2)}$. Constraints (8) and (9) are related to attacker awareness of the facilities established in the existing locations. The attacker considers that the defender has established facilities in sites 1 and 2; otherwise decides on facilities disturbance.

The objective function of the third level consists of two parts: (i) minimizing the cost of customer service inside the system and (ii) minimizing the cost of outsourcing services as shown in Expression (12). Relationships (14) and (13) ensure that each customer is assigned to a facility; otherwise, it will be provided through outsourcing. Equation (15) shows the defensive power of a defender. Constraints (16) and (17) show the capacity of each facility services. Based on these restrictions, the amount of the demand capacity allocated to each facility is the maximum size to the amount of the expected value of the facility's capacity after considering the condition of attacker's interdiction and defender's fortification. Relation (18) also refers to the defensive power of the defender. According to the number of facilities that are fortified should not be more than intended. Relationships (4), (5), (10), (11) and (18) to (22) are the the sign binary variables.

4. Solution Methods

Since the tri-level optimization problem is the developed version of the bi-level optimization problem and its family, in which all functions are continuous and NP-hardness, many efforts have been made to solve it due to the use and importance of bi-level programming. Computational methods for solving this problem can generally be divided into three categories (Sakawa and Nishizaki, 2009):

- Vertices counted approach, which is based on this specification, the extreme point of the set of decision-making lower-level rational answers, and an extreme point of the feasible region.
- Kuhn-Tucker approach, in which the upper-level problem with constraints to include low-level optimal conditions is solved.
- Penalty function approach, in which a penalty expression is added to the objective function to satisfy the optimality of the lower level.

The bi-level programming problem solving methods can be noted meta-heuristic methods. A meta-heuristic algorithm is an innovative method that can be optimized for various problems and used with small changes. Using meta-heuristic algorithms, the ability to find high-quality solutions for hard optimization problems is increased notably. Meta-heuristic methods have also been used to solve bi-level programming problems. A group of meta-heuristic algorithms is Single-Solution based (S-Metaheuristic) algorithms. Single-Solution based algorithms during the search process, change the answer and focus on local search. Some S-Metaheuristic algorithms are Simulated Annealing (SA), Iterative Local Search (ILS), Tabu Search (TS) and Noisy Method (NM). Also, the utilization of hybrid meta-heuristic and exact methods is convenient option for solving this class of problems (Talbi, 2013). Hence, we use to have a hybrid method to solve the model.

In detail, since all of the three levels of the model variables are binary, the problem is a pure integer programming. So in the first solving method, the third level of the model is coded in GAMS 24.1.3 software. Also, the first and second levels of the presented model are solved by an explicit enumeration method and coded in MATLAB 2012 software on some randomly generated data sets based on the approach proposed by in Aras et al. [16] on Intel (R) Core (TM) i5-3230M @ 2.60 GHz and 4/00 GB Ram. For ease, we name it EX-EX-EX (i.e., explicit enumeration for the first and second levels and exact solution for the third level).

Because exact methods cannot solve large instances, we propose a hybrid meta-heuristic algorithm and exact method. In fact, we use TS for the first level and an enumeration method for the second and third levels of the model, named as TS-EX-EX. Similarly, we use SA for the first level instead of TS in another method, named as SA-EX-EX). To clarify, in these combined methods, a heuristic approach deals to search the solution space model of the upper level. For each randomly generated solution, the amounts as parameter values are sent to a lower level. In this level, an exact solver after achieving an optimum solution for determining a competence solution usually returns to a top level. For a detailed study of TS and TS methods can refer to Pham and Karaboga (2012).

5. Computational experiments

In this section, the computational results to evaluate the model is presented. We tested performance of three solution algorithms on a number of instance, which have randomly generated. First and second level of the proposed hybrid algorithms was coding on software in MATLAB 2012.For the solution of third level of the model, for each response generated in the second level GAMS software was called. Codes on computers with processor Intel (R) Core (TM) i5-3230M @ 2.60 GHz and an internal memory of4/00 GB and Windows 7 operating system was running.

5.1. Generation of random test instance

We generate 12 THFLRIM instances in total, which n_k, R_j, n_j and R_j are a number of type 2 facility, rate of type 2 facility, number of type 1 facility and rate of customer nodes respectively. The instances in our test bed were named to be indicative of the n_k, n_j and number of example, values. For example, 263 means that there are 2 number 3 of example 2 facility sites, 6 type 1 facility sites and example 3. Also, rF_1, rF_2 and rC are radius of region for type 1 facility, radius of region for type 2 facility and radius customers node, respectively. The template of random instance generation is given in Table 1.

Table 1. Random problem generation template employed in the computational study

Parameters	Values
n_k	$\{2,3\}$
R_j	$\{2,3,4\}$
n_j	$n_k \times R_j$
R_i	$\{5\}$

n_i	$n_j \times R_i$
a_i	Random $\{20,30,...,150\}$
β_i	Random $\{0.1,0.15,...,0.3\}$
$d_{ij}^{(1)}, d_{ik}^{(2)}, d_{jk}^{(3)}$	Is calculated by the Euclidian distance. For example for $d_{ij}^{(1)} = \left[(x_i - x_j) + (y_i - y_j)\right]^{\frac{1}{2}}$
$c_j^{(1)}, c_k^{(2)}$	Capacity of each facility determined randomly, so that the capacity of each facility is more than the capacity that customers need.
B_{att}	$\{2500\}$
$b^{(1)}, b^{(2)}$	$b^{(1)} = 100$ and $b^{(2)} = 1000$
B_{def}	$\{2500\}$
$p^{(1)}, p^{(2)}$	$p^{(1)} = 100$ and $p^{(2)} = 1000$
$CS_{(1)}, CS_{(2)}$	$CS_{(1)} = 0.04$ and $CS_{(2)} = 0.5$
$CO^{(1)}, CO^{(2)}$	$CO^{(1)} = 3 \times CS_{(1)} \times 200 = 3 \times 0.04 \times 200 = 24$
	$CO^{(2)} = 3 \times CS_{(1)} \times 200 = 3 \times 0.5 \times 200 = 300$
$f_j^{(1)}, f_k^{(2)}$	$f_j^{(1)} =$ Random $\{500,550,...,1000\}$
	$f_k^{(2)} =$ Random

5. 2. Parameter calibration

The calibration parameters and assigning appropriate parameters affect on the solution quality of the algorithms. For parameter calibration of algorithms, several methods to statistically design the experiment are available. In this paper, to tune the parameters of the TS algorithm, we use a statistical methodology, called response surface methodology (RSM), introduced by GE and KB (1951). The RSM is used to estimate the optimal parameters affecting on the process. In this methodology, the regression equation analysis is used to evaluate the different levels of the parameters (Mohammadi et al., 2011, Mohammadi, Jolai and Tavakkoli-Moghaddam, 2013). In this method, a series of different levels of various parameters are studied and best-fit regression equation parameters on different levels, optimal values for the parameters are recommended. we should first determine the parameters of the algorithm, and then for each of the parameters considered two levels and desirable values of the parameters are achieved by fitting the best regression equation on different levels of the parameters. The tuned parameters of offered methods are shown in Table 2.

Table 2. TS and SA parameters settings.

Algorithm	Parameters	Setting	Algorithm	Parameters	Setting
	Max Iteration	19		Max Iteration	51
Tabu Search	TabuTenure	2	Simulated Annealing	SubMaxIteration	57
	Max Not Improve Length	5		T_0	186000
	Candidate List Size	3		Alpha	0.78

6. Analysis

6.1. Comparison of the results

After generating 12 random instances in three different sizes, the EX-EX-EX approach first calculates the optimum solution. Then, two other methods are used to solve samples, especially large instances. The objective function values of the first level, the optimal solutions variables and CPU time for each of instances are depicted in Table 3. The results show that each of the two parts of the first-level objective, Z_2 and fixed charge cost have different behavior. In fact, with the increase of fixed charge facility costs, reduced costs of current services. Eventually, the best solution is searched between the two exchanges. Also, the result of the TS algorithm compared with the SA algorithm show that the performance of TS is better in the CPU time and best solution (see Table 3).

Table 3.Computational comparison between TS-EX-EX and B-EX-EX method and EX-EX-EX

	SA-EX-EX				TS-EX-EX				EX-EX-EX			
Ins ID	Best solution	X_1^*	X_2^*	CPU time (Sec)	Best solution	CPU time (Sec)	X_1^*	X_2^*	Best solution	CPU time (Sec)	X_1^*	X_2^*
261	2738400	001000	01	2788	2692100	58	001000	11	2617100	2338	001000	11
262	4458600	100010	01	4728	3312500	540	100000	11	3222500	4825	100000	11
263	2981500	111100	01	1166	2787800	653	010010	11	2672800	5605	010010	11
264	5101800	110100	10	1329	2820000	857	000110	11	2765000	5419	000010	11
265	3937300	111010	01	1596	2858700	2772	010010	11	2858700	4542	010010	11
266	298600	100110	10	1273	2894100	3270	001010	11	2647300	5592	001010	11
281	570300	10110010	10	2789	2919300	1481	01000101	11	----------	---------	---------	---
282	4125200	10111000	10	6571	2842400	1430	00100100	11	----------	---------	---------	---
283	6198100	00011101	10	8652	5737500	9296	11111101	10	----------	---------	---------	---
361	----------	----------	-----	----------	4319000	9159	101101	011	----------	---------	---------	---
362	----------	----------	-----	----------	4689700	4974	101111	011	----------	---------	---------	---
363	----------	----------	-----	----------	2757900	6090	101110	101	----------	---------	---------	---

6.2. Sensitivity analysis

To verify the mathematical model behavior, a sensitivity analysis is carried out on a numerical example. To do this, by keeping all parameters and changing only one of them, we check the model behavior. The desired parameters to check their effect on the behavior of the model on the objective function, including attacker power and budget of interdiction (i.e., defensive power). The analysis results are shown in Tables 4 and 5 and Figure 1.

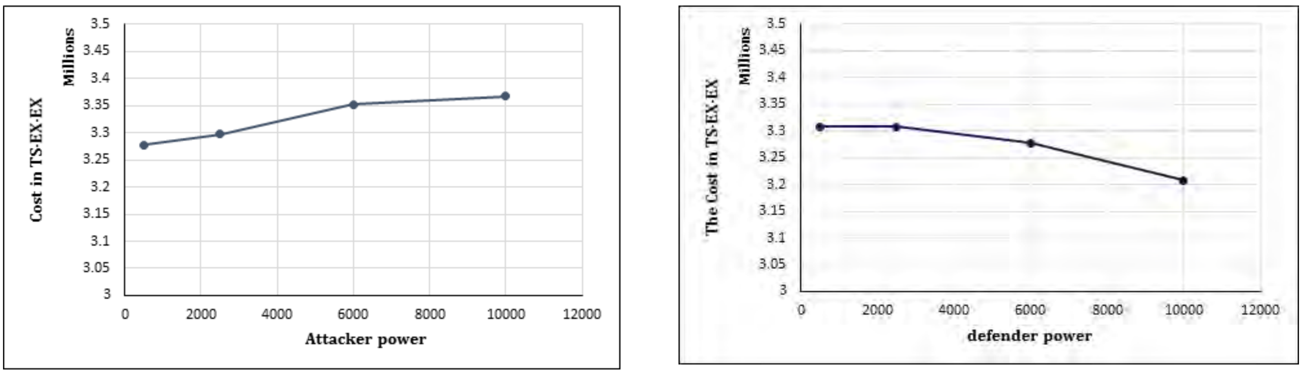
According to Table 4 and Figure 1(a), as expected in increasing in the attacker budget, the costs are increased. Because the attacker budget is more, further facilities are attacked and more facilities lose their service capacity. As a result, to satisfy customer's requirements, we need to increase capacity and further outsourcing. Furthermore, Table 5 shows that increasing the maximum number of the defensive system results in decreasing the cost as expected. Figure 1(b) depicts the trend of this change as well.

Table 4. Analysis of the interdiction budget on the cost.

Interdiction budget (attacker power)	Cost in TS
500	3277500
2500	3297500
6000	3352500
10000	3367500

Table 5. Analysis of the fortification budget on the cost.

Fortification budget (defender power)	Cost in TS
500	3307500
2500	3307500
6000	3277500
10000	3308000



(a) (b)

Figure 1. Analysis of (a) the interdiction budget, and (b) the interdiction budget on the cost

7. Conclusion

In this paper, we presented a mathematical model for designing a service system to protect its facilities with a focus on the most effective localization and proposed a tri-level facility location median model for hierarchical facilities (TFLRIM). A designer of the system (i.e., defender) could predict with a strategic vision and the vulnerability of the system against future problems and decide on the number and location of service facilities. The tri-level model has suggested in the form of the defender-attacker-defender. It is assumed that the facilities are hierarchically and capable of nesting. The attacker budget for interdiction and defender budget for fortification is limited. Since all three levels of the TFLRIM variables were binary, the problem was considered as a pure integer programming one. So, we obtained an exact solution by the explicit enumeration method on some randomly generated test problems. We proposed a hybrid meta-heuristic algorithm and exact solution (i.e., Tabu search (TS) and Simulated Annealing (SA) for the first level, and enumeration method for the second and third levels of the model) in order to solve larger instances. Additionally, for tuning of the algorithm parameters have used a statistical methodology, namely response surface methodology (RSM). After implementing algorithms on different instances, the results of the TS algorithm comparing with the SA algorithm show that the performance of TS was better in terms of the CPU time and best solution. The obtained results implied that the effect of correct locating strategies could reduce the facility costs exposed to disorder. We suggest that the problem can be modeled dynamically and internal failures of the system to be considered to outside attacks of the system.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Hybrid and Intelligent Price Forecasting Using Product Specifications

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Abstract

With the accelerating investments in information technologies and the advantages offered to the parties of transactions, e-commerce has been an irrevocable tool in both daily and business lives. It is also a fact that as the innovations and technological investments on e-commerce are continuously increasing, the industry volume is also expanding. Similar to the case in the conventional commerce systems, sales price of the products and services is basically one of the most determinant aspects of a transaction between the customer and the vendor. However, the customer may not always be fully aware of the price of a product or service; yet, can have intuitive estimates. In such cases, it is helpful to provide a price range or an exact price (if possible) to contribute to customer's decisions. Overwhelming majority of price forecasting models are applied to prices, oil prices and stock markets where temporal data is in abundance. The main objective of this study is to propose novel and intelligent models in the light of scientific developments for forecasting the sales prices of online services where temporal data is few. In this study, ANNs are hybridized with Simulated Annealing (SA) and Genetic Algorithm (GA) for price forecasting and their results are compared. The application is conducted on an e-commerce service provider and the inputs of the model are composed of exogenous variables, that are, service specifications and location of the related services. Results indicate that the performances of hybrid forecasting methods are helpful conventional statistical methods and ANN.

Keywords

Price forecasting, service specifications, Artificial Neural Networks (ANNs), Simulated Annealing (SA), Genetic Algorithm (GA)

1. Introduction

Signs of forecasting can be found in everyday lives. Weather, exam results, demand, and much more can be given as examples to the necessity of forecasting. These forecasts may seem to be dependent to very easy parameters, but one can say that they are actually quite complex in nature (Makridakis et al., 1998). Various methods of forecasting can be used in depending on the problem situation. Price forecasting is modeling forward demand based on the data obtained previous periods. Therefore, price forecasting models predict the changes on the price of the product or service. In literature, most of the price forecasting models are implemented for cost minimization that involve only financial factors, disregarding the price variation over market strategy and customer and buyer behavior. Therefore, models that involve indirect economic aspects such as customer behavior are important. (McMenamin and Monforte, 2000). Price forecasting and analysis is also essential for companies due to help meet the customer's expectations and developing marketing strategy (Amasaga, 2012).However, there are some cases in service industry where the customers are unaware of market prices. For example, house painting, decoration or plumbing and such services are needs that are not constantly required; people require such services once every couple of years. Hence, the current ongoing prices of these services may not be known by customers, especially in countries where the inflation rate is high. Such customers are aware of the pastime prices of these related services and only have a vague and intuitive estimate in their minds which is usually much lower than the current actual prices. In these situations, an online service provider of such services may have to aid the decisions of customers by informing them about the current market prices; because when customers face with higher prices than they expect, they churn. In order to save customers, they should be given an idea on how much their offers are going to cost them before they are offered the services they need. The prices of these services depend on the specifications and the location of the given service. As a result, such online platforms need a decision support system based on price forecasting where the price of a specific service is predicted through service specification and location.

The applications of price forecasting literature mostly involve electricity and energy, and stock markets using a wide range of methods. Early forecasting methods involve traditional and linear statistical models such as moving average, exponential smoothing, and ARIMA models that implement time series (Zhang, 2003).Although traditional statistical models are useful forecasting for short period of time, they have two basic constrains which are linearity and decreased accuracy in case of lack of temporal data (Khashei et al., 2008). In recent studies, intelligent methods, especially Artificial Neural Networks (ANNs) are shown to be more accurate in case of nonlinearity and the lack of temporal data. The most important feature of ANNs in contrast to traditional statistical models is that ANNs are data-driven and self-adaptive. In addition, ANNs can generalize and universal functional approximations. Finally, artificial neural networks have flexible nonlinear modeling capability (Zhang et al., 1998)

Most recently, hybrid models or combining several models are common used to forecast prices. In this way, forecasting accuracy and performance are improved by capturing different patterns by each model's unique feature (Zhang et al., 1998). Results of such studies indicate that hybridizing different models is an effective and efficient way to improve forecast quality (Khashei and Bijari, 2011).In this study, a price forecasting decision support system for an online inhouse services provider is constructed using ANNs hybridized with two metaheuristics: Simulated Annealing (SA) and Genetic Algorithm (GA). The results of these models are compared using a t-test. The rest of the paper is organized as follows: the literature review is presented in the next section and methodology is provided for proposed system in the following section. Section 4 presents the application and its results. In Section 5 concluding remarks are given.

2. Literature Review

The methods developed to forecast sales prices are quite various; yet, the application considering product specification is very limited. Hence, a general review is conducted to overlook and determine appropriate methods for the presented problem in the previous section. The classification of these models are dependent on application areas according to the related literature. Aggarwal et al. (2009) classifies electricity price forecasting methods in three main groups game theory, simulation models, and intelligent models. In the game theoretical approach, finding the equilibrium point of the price with regard to demand is the key point. These models are mentioned to be essential in case of highly uncertain demand that fluctuates greatly even in short term predictions and the bids for prices are affected by both parties (Rudkevich, 2005).The second class that Aggarwal et al. (2009) offer subsumes simulation models. Forecasting using a simulation model involves a physical system and its conceptual and simulation model to optimize a flow in electricity systems (Liu and Shi, 2005). However, considering these two classes, in the case of online home services providers, the demand is very stable compared to electricity markets, they are not affected from temporal data as in the case of electricity and stock markets, and, lastly, the customers do not have a major part in price determination; so game theoretical approaches are not proper for such problems. Moreover, the problem is not physical enough to be treated a simulation approach.

The third class of Aggarwal et al. (2009) involves time series models which constitute the majority of the forecasting literature. These models use numerical, tangible data rather than abstract data where models are formed that use past numerical data for forecasting (Stevenson et al., 2008). In this way, time-series analyses provide a relation between time and the actual output to be forecasted. There are diverse different approaches in time series forecasting. Aggarwal et al. (2009) subsets this class as traditional statistical models and Artificial Intelligence (AI) techniques. Traditional statistical models a great deal of methods. The basis of such models have been built upon Autoregressive (AR) and Moving Average (MA) models, and involve their integrations and developed versions such as Autoregressive Moving Average (ARMA), Autoregressive Integrated Moving Average (ARIMA), etc. which were developed by Box and Jenkins (1976, 1994). These methods are mostly used to convert a non-stationary time series into stationary and in practice, majority of the real-world data is non-stationary (Weron and Misiorek, 2010).In the literature, various combination models have been proposed with a specific end goal to enhance forecasting performance. For instance for time series data exhibit seasonality, a variation of ARIMA model which called SARIMA (Seasonal-ARIMA) has proposed by Box and Jenkins (Adhikari and Agrawal, 2013). Chin and Mital (1998) forecast Singapore property prices by using

ARIMA with optimal control approach. Zhou et al (2006) use widened ARIMA to forecast electricity prices where the ARIMA method is widened to forecast the error correction and hourly market balance price using confidence intervals. Garcia et al. (2005) propose GARCH method for price forecasting in electricity prices. In GARCH method the term "error" is considered a series correlation and can be applied AR. However, the issue with these methods is that the linear structure of these models may not reflect the true structure of the pricing scheme. Zhu and Wei (2013) propose use of an ARIMA for price forecasting and declare nonlinearity is an issue for such methods. Nogales (2002) attempt to overcome the linearity challenge by nonlinearizing regression with the implementation of transfer functions.

A strong alternative for traditional statistical methods is the implementation of AI techniques where ANNs are the major candidates. Inspired by the human brain information processing techniques, ANNs have the capability to capture the nonlinear data pattern have been developed and used in time series forecasting. When selecting the method of forecasting, forecasting accuracy is most important factors taken into consideration. Artificial neural networks (ANNs) are flexible computing frameworks and can applied to forecasting models with a high degree of accuracy (Khashei et al, 2008). McMenamin and Monfronte (2000) compare the statistical approaches for electricity prices to ANNs and conclude that the implementation of ANNs improves forecast accuracy by 25%. Gao et al (2000) forecasted power market clearing prices using Neural Network method on a three-layer network with Backpropagation. Kohzadi et al. (1996) compare statistical methods and ANNs while forecasting commodity prices. ARIMA is used as a time series method while Feedforward Neural Networksare chosen as a neural network. The data used in the article is the cattle and wheat prices between 1950-1990. The comparison demonstrates that ANN model yields 27-56% better results than ARIMA in terms of MSE.In addition, various ANN structures are also used for forecasting. Least Squares Support Vector Machine (LSSVM) models are one of the recent approaches in literature. Lee et al (2010) proposed LSSVM for price forecasting. In order to improve the accuracy of LSSVM model, experimental data is normalized and suitable parameters are chosen by genetic algorithms. Zhu and Wei (2013) compare ARIMA and LSSVM for forecasting carbon prices and conclude that LSSVM can be used for catching non-linear patterns while ARIMA is used for catching linear ones. When ANNs are hybridized with other methods, the forecast accuracy improves more. Kozaki and Baba (1993) propose a hybrid algorithm which combines random optimization with a Back-Propagation method in order to forecast stock prices in Japan where 15 input variables are determined as key factors. Pai and Lin (2005) proposed a new hybrid method consisting of ARIMA and SVM models. In order to compensate the nonlinearity problem, the implementation of SVM is found to be of vital importance. Other, implementations of AI includes Fuzzy Logic approaches. Leu et al (2010) proposed a Neural Network and Fuzzy Time Series hybrid called FTSSN to forecast option prices and state that merging ANNs' ability to learn and find the best and fuzzy logic's ability to decide like a person and provide expertise yield the best results.

Unlike most of the studies, this study does not involve any time series data. However, the price of the services are to be determined by exogenous variables that are, the service specifications and the location where the service is offered. Yet, the ability of ANNs to use exogenous variables as inputs enable to forecast prices for such problems (Aggarwal et al., 2009). Ye et al. (2005) implement an ANN structure with exogenous variables such as the date. Lira et al. (2009) include reservoir levels and demand as exogenous variables and predict Colombian electricity prices. However, the parameters of ANNs are hard to determine and require tuning before execution. Metaheuristic methods are widely used for tuning ANN parameters. Sexton et al. (1999) tune learning rate for ANNs. Likely, Bashiri and Geranmayeh (2011) tune ANN parameters using Genetic Algorithms. In this study, we also implement Simulated Annealing and Genetic Algorithms for training ANN parameters and compare their results statistically.

3. Methodology

3.1. ANNs

ANNs, inspired by the human brain information processing techniques, simulate the simple biological nervous system. Simulated neural cells are called neurons. These neurons form a network connected to each other in various ways (Dobranzski, 2014).

A back-propagation network is an ANN that uses a learning algorithm and a feed-forward architecture. In this model, there is no connection between the neurons in the same layer. However, every neuron in a layer is connected to each neuron in the next layer and feeds them input. In a back propagated network model, there are minimum three layers called input, hidden and output. Data enters the net from the entry point, and then is passed on to hidden layer. Hidden layer is where the data is processed. This layer processes the data it received with a suitable function and sends it to the next layer. Output layer is the last layer of the ANN. The output of the output layer is the final output of the network. Number of hidden layers can change based on the complexity of the problem (Minghua et al., 2012).

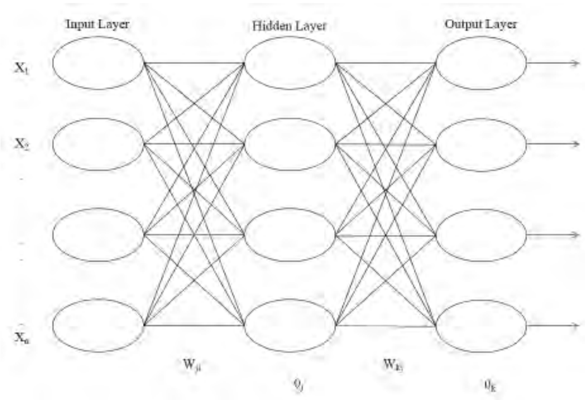

Figure 1: Structure of Back Propagation ANN (Panda, Chakraborty & Pal, 2007)

In the figure, Structure of a Back Propagation ANN model is demonstrated. In these figure, input neurons are denoted by *l,* hidden layers are denoted by *m* and output neurons are denoted by *n*. W_{ji} and W_{kj} is weight factor that provide connection of i^{th} node of first layer to j^{th} node of the second layer. Sigmoid transfer function is sum of the modified signals (Chou et al, 2003).

The formulas are

$$o_{pi} = l_{pi} \tag{1}$$

where o_{pi} is the p^{th} output from i^{th} neuron in the input layer and l_{pi} is the p^{th} pattern of i^{th} neuron in the input layer.

Output from a neuron in the hidden layer is,

$$o_{pj} = f(\textstyle\sum_{i=0}^{1} w_{ji}\, o_{pi}) \tag{2}$$

where o_{pj} is the p^{th} output from j^{th} neuron in the hidden layer and w_{ji} is the weight of j^{th} neuron in the hidden layer and i^{th} neuron in the input layer.

Output from a neuron in the output layer is $f(\sum w_{kj}\, o_{pj})$, where w_{kj} is the weight of j^{th} neuron in the hidden layer and k^{th} neuron in the output layer.

where $f()$ is the sigmoid transfer function whose formula is

$$f(x) = 1/(1 + e^{-x}) \tag{3}$$

During training, Mean Square Error is calculated by comparing the predicted output and the desired output.

Mean Square Error, E_p for pattern p is,

$$E_p = \sum_{i=1}^{1} \frac{1}{2} (D_{pi} - O_{pi})^2 \tag{4}$$

where D_{pi} is the i^{th} target output for the p^{th} pattern, and O_{pi} is the computed output i^{th} target output for the p^{th} pattern.

Weight change at any time t, is,

$$w(t) = \eta \frac{\partial E_p(t)}{\partial W} + w(t-1) \tag{5}$$

where η is the learning rate and t is the index for iterations.

In this study, a four-layer network, which has two hidden layers, is used. Three parameters are tuned: the learning rate, number of neurons in the hidden layers (first and second hidden layer, respectively).

3.2. Simulated Annealing (SA)

SA is a search algorithm which is proposed by Kirkpatrick et al in 1983 for finding the global minimum of function. It is based on simulating process of metals' heating then cooling slowly for crystallizing. Temperature value is used for determining the probability of a worse solution than the best solution obtained (Liu et al., 2013).

The process of the simulated annealing algorithm is as follows,

Step 1: Determine initial parameters related with search.

Step 2: Select the initial system temperature T and a random starting point which is calculated as

$$x_0 = x_{min} + rn(x_{max} - x_{min}) \tag{6}$$

for a continuous problem. In this formula, x_0 is the starting point, x_{min} is the minimum value that the variables can have, x_{max} is the maximum value the variables can have, and rn is a uniformly distributed random number between 0 and 1. In the parameter tuning problem, learning rate is a continuous variable and takes values between 0 and 1. However, the number of layers in the hidden layers is an integer. These numbers are assumed to be limited to 16 for saving execution time while still providing enough neurons to allow the network accurately reflect the actual system. A sample solution is given below

0.65	0	1	1	0	0	0	0	0

Figure 2: A sample solution

In this sample solution, the first number, that is, 0.65 is value encoded and is the learning rate. The next four binary digits are in the binary form and signify the number of neurons in the first hidden layer. In this solution, these numbers are 0110 and when converted to decimal form, it is equal to 6. This number is one less than the number of neurons in the first hidden layer, which makes the number of neurons 7. The last four digits signify the number of neurons in the second hidden layer. Here, the decimal encoding is 0. Since, at least one neuron is necessary for a layer, this number is one less than the number of neurons in the second hidden layer, which is 1.

Step 3: Find the objection function value of the initial point. In this problem, the objective function values are outcomes of the ANN algorithm and minimizing the Mean Absolute Percentage Error (MAPE) of the ANN is the objective. However, ANNs are methods that involve randomization, which is why a good or a bad result may just be a coincidence. In order to make sure that the obtained results are not coincidental, every time an objective function is calculated, the ANN is run for 30 times and the average MAPEs of these 30 runs are assigned as the objective values.

Step 4: Go to a random neighbor of this point.

$$x_{i,neighbor} = x_i \pm rn \cdot \delta \cdot (x_{max} - x_{min}) \tag{7}$$

where δ is the neighborhood rate for the continuous case. The neighbor for learning rate is calculated in this manner. The neighbor for the number of neurons in the first and the second hidden layers is found by bit conversion. A random bit for each part is selected. If this bit is 1, it is converted to 0 and vice versa.

Step 5: If the objective function value of the neighborhood point is better than the initial point, this neighboring point is accepted as the new initial point. Otherwise, the acceptance probability is assigned as.

$$p_a = e^{-\Delta f/T} \tag{8}$$

where Δf is the worsening amount of the objective function value and T is the temperature of the related iteration. The neighboring point is accepted only if a uniformly distributed random value between 0 and 1 is less than the acceptance probability p_a.

Step 6: The system temperature is decreased using the following formula:

$$T_{new} = \alpha T_{old} \tag{9}$$

Step 7: Steps 3-6 are repeated until a final temperature is reached.

3.3. Genetic Algorithm (GA)

GA codes all the points in the solution space using different coding schemes. Each solution is called a chromosome and the algorithm solves the problem using a set of chromosomes, namely, a population. In every generation, the algorithm forms a new population by using genetic operators using selection, crossover and mutation (Goldberg, 1989).

The process of the genetic algorithms is as follows:

Step 1: An initial population proper to the problem is generated. The chromosomes are constructed as the solutions of the SA algorithm.

Step 2: The fitness function values of all chromosomes in the population are calculated similar to the case of SA. The fitness value of the i^{th} chromosome is shown by f_i.

Step 3: An appropriate selection method is applied. In this study, the roulette wheel selection method is utilized. The roulette wheel is a maximization based selection method. Hence, before applying this method fitness function values are inverted as $1/f_i$. This method aims to get rid of weak chromosomes and allow strong chromosomes to reproduce. The probability of survival (p_i) is calculated as

$$p_i = \frac{1/f_i}{\sum 1/f_i} \tag{9}$$

Step 4: An appropriate crossover method is applied. Crossover operator provides diversity among the population. In this study, one point crossover is implemented. In one point crossover, a random crossover point is selected and genes after this crossover point are exchanged between parents.

Step 5: An appropriate crossover method is applied. In this problem, mutation scheme is applied similar to the neighboring process in SA. The learning rate is slightly changed and binary bits are converted.

Step 6: Steps 2-5 are repeated until convergence is caught.

4. Application and Results

The price forecasting application is achieved using the data of an online home related service provider and the category of wall painting is selected since because of involving the most data. Customers that are members of this site fill out a form to specify their needs and when a customer fills a demand request form. This form involves multiple choice questions that ask for details of the service. For the wall painting category, these multiple choice questions involve the surface are and the number of rooms to be painted, the quality of the paint, etc. The database holds the index of these choices but does not hold what these indices refer to. Moreover, the prices change from one district to another.

Some sample data is presented below:

Order Number	Choice index	Location	Price
1	5	138	1250
1	9	138	1250
1	10	138	1250
1	19	138	1250
1	20	138	1250
2	1	186	1220
2	8	186	1220
2	18	186	1220
2	19	186	1220

Figure 3: Sample data

The data given in Figure 3 has two orders. Order 1 is at a location that is coded as 138 and the customer has selected options 5, 9, 10, 19 and 20. The order is fulfilled and the price is 1250 Turkish Liras. Likely, order 2 is at a district coded with 186 and the customer has selected options 1, 8, 18 and 19. The order is fulfilled for 1220 Turkish Liras. Due to page limit concerns, not all orders and options for these two orders are presented. The problem has a total of 4552 data points with 756 orders which involve 24 districts and 20 options.

In order to process these data using ANNs, the inputs (choice index and location) are converted into binary bits as given in Figure 4.

Order Number	1	2	3	4	5	...	19	20	20	29	54	72	81	89	138	...	156	160	161	163	180	186
1	0	0	0	0	1	...	1	1	0	0	0	0	0	0	1	...	0	0	0	0	0	0
2	1	0	0	0	0	...	1	0	0	0	0	0	0	0	0	...	0	0	0	0	0	1

Figure 4: Processed data

These zeros and ones constitute the input of the ANNs as given in Figure 5.

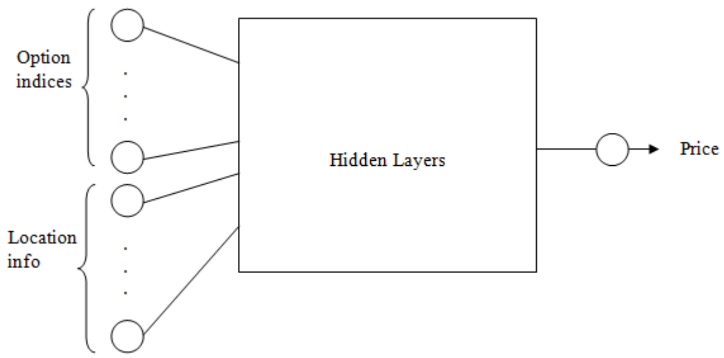

Figure 5: The ANN structure

After the parameters of the ANN are tuned with SA and GA separately, the ANN is run with the tuned ANN is run 100 times in order to compare the differences between both hybrids. The optimized parameters and the results are presented in the table below:

Table 1: Tuned parameters and results of 100 runs

	SA+ANN	GA+ANN
Learning rate	0.7924	0.7922
The number of neurons in the first hidden layer	8	13
The number of neurons in the second hidden layer	7	15
The mean of 100 runs with tuned parameters	0.207	0.209
The standard deviation of 100 runs with tuned parameters	0.042	0.033

The hypothesis of $H_1 = \mu_{SA+ANN} \neq \mu_{GA+ANN}$ and $H_0 = \mu_{SA+ANN} = \mu_{GA+ANN}$ is constructed, and the t test with above-given means and standard deviations yields a *p* value of 0.5855.According to t-test results, difference is considered to be not statistically significant. Due to insufficient evidence to prove alternative hypothesis, H_1 is rejected. Statistical results indicate that SA model and GA model have equal performance. However, the SA model more preferable than GA model because of time constraint for our data.

5. Conclusions

Price forecasting is an essential tool for many industries. In some cases, the price is determined by the equilibrium of the supply and the demand, whereas in some cases it is a function of the past data. However, services such as wall painting and home decoration are infrequent and in a way, non-repetitive customer needs for whose prices customers have very little information on. In such cases, it may be a service provider's duty to aid the decision of customers by also providing price information beforehand so that the customers do not churn.

In this study, the price forecasting for an online home services provider is achieved using ANN hybrids with both SA and GA. While both methods have promising results, there is no significant difference between GA and SA models. Statistical results clearly show that the performances of two models are equal. However, the SA model requires lower time than GA model. Therefore SA model is proposed due to time advantages. Future studies involve the exploration of other forecasting algorithms and improved versions of ANNs.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Three Meta-Heuristic Algorithms for Efficient Truck-Door Assignment and Product Placement Plans in Cross-Docking Centers

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Abstract

Cross-docking is a relatively new logistics strategy in which items are moved from suppliers to customers through cross-docking centers without storing the products for a long time. In cross-docking centers, products are unloaded from incoming trucks, consolidated according to their destinations, and then, loaded into the outgoing trucks for distribution to customers. For the efficiency of these processes it is critical to specify the truck-door assignment and product placement plans in these centers. This paper addresses the truck-door assignment and product placement problem in cross-docking centers to obtain effective operational plans in cross-docking centers. The truck-door assignment problem of cross-docking system can be described as finding the best assignment plan of the incoming and outgoing trucks to dock doors. In addition to the truck-door assignment problem, this study considers the product placement decisions in cross-docking consolidation area to identify operations and movements more realistic in these centers. The problem is formulated with a linear mathematical model which aims to find best truck-door assignment and product placement plan that minimize total travelling distance of products. To deal with the complexity of the problem, three meta-heuristic approaches, simulated annealing (SA), tabu search (TS) and genetic algorithm (GA), are proposed. In computational studies, the performance of the proposed SA, TS and GA are tested on various different sized randomly generated problem by comparing the best and average results of the algorithms. The results show that the proposed GA performs better in comparison with the other two meta-heuristic methods.

Keywords

Cross-docking, truck-door assignment, meta-heuristic algorithms

1. Introduction

The efficiency of transportation is one of the most important factor for supply chain management. For this reason, many companies develop various strategies to boost customer satisfaction and bring down the total costs. Cross-docking is one of these strategy and has a great potential to bring considerable reduction in the distribution cost by eliminating the redundant storage (Ladier & Alpan, 2016; Yazdani, Naderi, & Mousakhani, 2015). The cross-docking system can be described as the process of moving products from suppliers to customers through cross-docking centers without storing products for a long time. In the cross-docking network, the products are unloaded from incoming trucks at inbound doors and consolidated according to their destination. After the consolidation operations products are reloaded to outgoing trucks at outbound doors for distribution. In short term decision level of the cross-docking system, the operational plans such as transportation, truck-door assignment, consolidation, product placement, scheduling, etc. play an important role to increase efficiency of the system (Staudt, Alpan, Di Mascolo, & Rodriguez, 2015; Van Belle, Valckenaers, & Cattrysse, 2012). In order to minimize total material handling costs in cross-docking centers, this study considers the truck-door assignment problem of cross-docking system with product placement operations which is called as truck-door assignment and product placement problem in cross-docking center. The truck-door assignment problem in cross-docking centers can be described as finding the optimal assignment plan of incoming and outgoing trucks to inbound and outbound doors, respectively (Ladier & Alpan, 2016; Van Belle et al., 2012).

The earliest study for the truck-door assignment problem is presented by Tsui and Chang (1990) where a bilinear program is proposed for assigning the origins and destinations to dock doors. The authors also proposed a simple heuristic approach to solve problem. The same authors later proposed an improved version of the heuristic approach (Tsui & Chang, 1992). Cohen and Keren (2009) expanded the same problem by allowing the freight splitting for capacitated trailers and proposed a heuristic algorithm to solve problem. Oh, Hwang, Cha, and Lee (2006) considered the truck-door assignment problem for a real life case of a mail distribution center. The problem is formulated as a non-linear mathematical model and solved by two heuristic methods proposed by the authors. Bozer and Carlo (2008) studied the static and dynamic truck-door assignment problem, in which the outbound doors are fixed over the planning horizon for static door assignment problem while the assignment plans are re-formed every day for dynamic doors assignment problem. The static truck-door assignment problem is also taken into account by Yu, Sharma, and Murty (2008). The authors developed two heuristic methods which provide approximately 20% reduction in man-hour requirements. Miao, Lim, and Ma (2009) considered the truck-door assignment problem with operational time constraints and proposed a tabu search and a genetic algorithm for the problem. Luo and Noble (2012) considered the truck-door assignment problem with staging operations where the products are assigned to a lane in cross-docking center for storage. The authors developed a genetic algorithm to solve the large sized problems. Miao, Cai, and Xu (2014) proposed an adaptive tabu search algorithm for the similar problem where operational time constraints are considered. Nassief, Contreras, and As' ad (2016) presented a new mixed integer mathematical model for the truck-door assignment problem which is embedded into a Lagrangean relaxation.

In order to find efficient assignment plans for the large sized truck-door assignment and product placement problems, this paper proposes three meta-heuristic algorithms: simulated annealing (SA), tabu search (TS) and genetic algorithm (GA). The proposed meta-heuristic algorithms are tested on different sized problems which are generated by using a real-life data of a logistic company and compared their solutions with each other. The rest of the paper consists of the following parts: problem definition and mathematical model, proposed meta-heuristic algorithms, computational results and finally conclusion.

2. Problem Definition and Model Formulation

In truck-door assignment and product placement problem in cross-docking center, the products picked up from suppliers are unloaded from incoming trucks at inbound doors and moved to the temporary storage area after consolidation operations. Subsequently, products are transferred from temporary storage area to outbound doors according to their destinations and loaded into the outgoing trucks for distribution. The objective of the problem is to find best assignment and placement plans in cross-docking center to minimize total travelling distance of the products. In this study, the truck-door assignments and product placement plans are taken into account with the following assumptions:

- Each truck can be used for only one location and also each location can be serviced by one incoming/outgoing truck, which means that each supplier/customer location is assigned to an inbound/outbound door in cross-docking center.
- Inbound and outbound doors are separated according to the picking up and distribution operations. The suppliers can be assigned to only inbound doors. Likewise, the customers can be assigned to only outbound doors.
- Material flow in cross-docking center is formed in two stage: First, products unloaded at inbound doors are transported to temporary storage area after consolidation. Then, products are carried to outbound doors for distribution.
- The temporary storage area of the cross-docking center consists of a set of shelves.
- Movements of the pallets in cross-docking center are described as rectilinear distance.

According to the assumptions described above, the mathematical model of the truck-door assignment and product placement problem is formulated as follows:

<u>Parameters and Notations</u>

S : Set of suppliers

C : Set of customers

P : Set of products transported from suppliers to customers

DI : Set of inbound doors in cross-docking center

DO : Set of outbound doors in cross-docking center

D : Set of doors in cross-docking center; $D = DI \cup DO$

K : Set of available shelves at consolidation area

l_i : Supplier label of product *i*; $\forall i \in P$

l'_i : Destination label of product *i*; $\forall i \in P$

t_{id} : Travelling distance from door *d* to shelf *k*; $\forall d \in D; \forall k \in K$

Decision Variables

x_{ikd} : is a binary variable and equal to 1 if product *i* is carried from inbound door *d* to shelf *k* and 0 otherwise; $\forall i \in P; \forall k \in K; \forall d \in DI$

y_{ikd} : is a binary variable and equal to 1 if product *i* is carried from shelf *k* to outgoing door *d* and 0 otherwise; $\forall i \in P; \forall k \in K; \forall d \in DO$

Model

$$Min \;\; z = \sum_{i \in P} \sum_{k \in K} \sum_{d \in DI} t_{id} x_{ikd} + \sum_{i \in P} \sum_{k \in K} \sum_{d \in DO} t_{id} y_{ikd} \tag{1}$$

Subject To

$$\sum_{k \in K} \sum_{d \in DI} x_{ikd} = 1 \qquad \forall i \in P \tag{2}$$

$$\sum_{k \in K} \sum_{d \in DO} y_{ikd} = 1 \qquad \forall i \in P \tag{3}$$

$$\sum_{d \in DI} x_{ikd} = \sum_{d \in DO} y_{ikd} \qquad \forall i \in P; \qquad \forall k \in K \tag{4}$$

$$\sum_{k \in K} x_{ikd} + \sum_{k \in K} x_{jkd} \leq 1 \qquad \forall i, j \in P; \qquad l_i \neq l_j; \qquad \forall d \in DI \tag{5}$$

$$\sum_{k \in K} y_{ikd} + \sum_{k \in K} y_{jkd} \leq 1 \qquad \forall i, j \in P; \qquad l'_i \neq l'_j; \qquad \forall d \in DO \tag{6}$$

$$x_{ikd} \in \{0,1\} \qquad \forall i, j \in P; \qquad \forall d \in DI \tag{7}$$

$$y_{ikd} \in \{0,1\} \qquad \forall i, j \in P; \qquad \forall d \in DO \tag{8}$$

The objective function (1) aims to minimize total travelling distance of the products in cross-docking center. Constraint (2) specifies the movements of products from inbound doors to shelves and ensures that each product can be assigned to only one inbound door and also to only one shelf. Likewise, constraint (3) considers the assignments for the products from shelves to outbound doors. Constraint (4) maintains the continuity of the movements of products from inbound doors to outbound doors. Constraints (5) and (6) provides that more than one supplier or customer cannot be assigned to an inbound or outbound door, respectively. Constraints (7) and (8) define the binary decision variables.

3. Proposed Meta-Heuristic Algorithms

Because of the exact solvers are not capable to find effective solution for large sized problems, three meta-heuristic algorithms SA, TS, and GA are proposed in this study and the performance of the algorithms are tested in computational studies. To make impartial comparisons in computational studies, the basic structures of the algorithms are adapted to problem. For each algorithm, the solutions are represented with a priority based permutation encoding of the products. The assignment plans are determined with respect to the encoded order of the products. According to the representation scheme an objective function value of a solution is determined by assigning the products to the shelves by using the following steps:

Step 1 : Select the first product from priority list which is not assigned to any shelf.

Step 2 : If product's supplier and customer are assigned to an inbound and outbound door, go to the step 4.

Step 3 : Assign the product's supplier/customer location to first available inbound/outbound door.

Step 4 : Assign the product to a shelf which brings the minimum movement from inbound door to outbound door.

Step 5 : Update the availability of the selected shelf.

Step 6 : Go to step 1 until assignments of the products are completed.

3.1. Simulated Annealing Algorithm

SA is a stochastic method proposed by Kirkpatrick, Gelatt and Vecchi in 1983 to solve combinatorial problems (Kirkpatrick, Gelatt, & Vecchi, 1983). SA uses a stochastic approach to guide the search and in order to obtain better solutions, and allows the search to proceed to a neighboring state even if the move causes the value of the objective function to become worse. SA processes the local search in the following way. If a move to neighbor X' in neighborhood ensures improvement in objective value, or leaves it unchanged, then the move is always accepted. More precisely, the solution X' is accepted as the new solution if $\Delta \leq 0$, where $\Delta = f(X') - f(X)$ and $f(X)$ is the value of objective function. Moves, which increase the objective function means that $\Delta > 0$, are accepted according to a probability function $e^{(-\Delta/T)} > \theta$, where *T* is the parameter of temperature, and θ is a random number between [0, 1]. The value of *T* varies from a relatively large number to a small value close to zero, which is often controlled by linear equations for reducing temperature linearly. The steps of the SA algorithm are presented in Figure 1.

T = Initial temperature
c = Cooling parameter
$X^{best} = \varnothing$
Generate *X*
$X^{best} = X$
Do
    Generate X' from *X* by using a local search method
    If $f(X') < f(X)$ **Then**
        $X = X'$
    Else
        $\Delta = f(X') - f(X)$
        If $e^{(-\Delta/T)} > random[0,1]$ **Then**
            $X = X'$
        End If
    End If
    $T = T \times c$
    If $f(X) < f(X^{best})$ **Then**
        $X^{best} = X$
    End If
Loop Until (Stopping criteria)

Figure 1: Steps of the SA algorithm

3.2. Tabu Search Algorithm

Tabu search was introduced by Fred Glover in 1986 as an iterative meta-heuristic that guides a local search heuristic procedure to explore the solution space beyond local optimality (Glover, 1989, 1990). In each iteration, TS generates a solution neighborhood via moves. The TS algorithm is different from the SA algorithm in that the tabu search includes a memory mechanism that prevents the search from cycling back to previously visited solutions. The memory mechanism that maintains the search history is called the tabu list. The tabu list keeps either some of the moves or just their attributes, and reversing these moves is forbidden for a given number of iterations. However, this restriction can be ignored if the attempted move leads to a new globally optimal solution; this is called the *aspiration* criterion. This criterion allows for exceptions from the tabu list, if any move leads to promising solution. Also, several additional elements like intensification and diversification strategies may be included in the search strategy to improve the effectiveness of the TS method (Kirchler & Calvo, 2013). The steps of the TS algorithm are presented in Figure 2.

```
Empty tabu list
X^best = ∅
Generate X
X^best = X
Do
    Do
        Find best neighbor X' according to a local search method
        If f(X') < f(X^best) Then
            End Loop
        End If
    Loop Until ( X' is not tabu)
    Add move to tabu list and update tabu list
    X = X'
    If f(X) < f(X^best) Then
        X^best = X
    End If
Loop Until (Stopping criteria)
```

Figure 2: Steps of the TS algorithm

3.3. Genetic Algorithm

Genetic algorithm, which was first introduced by John Holland in 1975, is one of the stochastic search algorithms based on the evolutionary process of natural systems (Holland, 1992). Distinctly from the conventional search techniques, GA starts with an initial set of random solutions called population where each individual of the population is called as chromosome. In order to optimize any problem, the algorithm uses genetic operators such as selection, crossover and mutation. These operators are respectively applied to population after a fitness value is assigned to each chromosome. In selection procedure, the relatively fit chromosomes are selected from the population to be part of the reproduction process. In reproduction process, new individuals are created through application of crossover and mutation operator. Crossover operator explores the search space by blending the genetic information between the chromosomes and mutation operator maintains the adequate diversity by randomly changing some information in chromosomes (Goldberg, 1989). The steps of the GA are presented in Figure 3.

```
PS = Population size
CR = Crossover ratio
MR = Mutation ratio
X^best = ∅
Generate population X
Do
    Calculate the fitness value of the individuals
    Do
        Apply selection operator
        Apply the crossover operator
        Apply mutation operator
    Loop Until (New population is formed)
    Update the X^best from new population
Loop Until (Stopping criteria)
```

Figure 3: Steps of the GA

4. Computational Results

In order to evaluate the performance of the proposed algorithms, a small sized and a large sized problem set, which totally consist of 20 different sized instances, are randomly generated by using a real-life data of a logistics company. The proposed SA, TS and GA are developed in the Visual Basic programming language, and numerical experiments are carried out for each instance on 2.20-GHz Intel Core i7 processor with 8-GB memory. For the proposed SA and TS, insertion and shifting procedures are randomly applied as a neighborhood generation mechanism. Additionally, the tournament selection method and ordered crossover procedure are carried out for the proposed GA. For the computational studies, the parameters of the algorithms are set to a specific number which are presented in Table 1.

Table 1: Parameter values of the SA, TS, and GA

SA	TS	GA
Maximum Iteration : 1000	Maximum Iteration : 1000	Maximum Generation : 1000
Initial Temperature : 1000	Tabu List Length : 20	Population Size : 15
Cooling Rate : 0.95		Crossover Ratio : 0.70
		Mutation Ratio : 0.10

Table 2 and Table 3 show the results of the computational tests performed for small sized and large sized problem set, respectively. For each instance, algorithms are executed 10 times and the results are identified with average solution of the runs. Moreover, the performance of the algorithms are pointed out by comparing the results obtained by Gurobi Solver 6.0.4 with two hour time limitation. The gap between a meta-heuristic solution and best integer solution of Gurobi is specified by using Equation (9) where negative variable obtained with the formulation indicates that the meta-heuristic solution is better than the best integer solution of Gurobi.

$$\%Gap = \frac{Heuristic\,Solution - Gurobi\,Solution}{Gurobi\,Solution} \times 100\% \tag{9}$$

Table 2: Algorithm solutions for small sized problem set

		Gurobi Solution		SA Solution			TS Solution			GA Solution		
Problem No	**NP**	**OFV**	**CPU Time (s)**	**OFV**	**CPU Time (s)**	**%Gap**	**OFV**	**CPU Time (s)**	**%Gap**	**OFV**	**CPU Time (s)**	**%Gap**
1	43	5359.5	6.93	5359.9	1.73	0.01	5359.6	1.75	0.00	5359.5	1.27	0.00
2	44	5530.6	11.96	5531.1	1.82	0.01	5531.1	1.86	0.01	5530.7	1.73	0.00
3	41	5044.6	9.43	5044.7	1.66	0.00	5044.6	1.68	0.00	5044.6	1.93	0.00
4	63	7946.3	181.00	7948.2	2.43	0.02	7950.2	2.55	0.05	7946.3	1.69	0.00
5	37	5036.6	40.69	5037.0	1.63	0.01	5036.6	1.62	0.00	5036.6	1.23	0.00
6	46	5862.6	13.33	5863.7	1.87	0.02	5863.7	1.87	0.02	5862.6	1.80	0.00
7	33	4730.3	30.85	4730.3	1.53	0.00	4730.3	1.50	0.00	4730.3	1.19	0.00
8	49	6291.7	163.00	6292.5	2.20	0.01	6295.3	2.18	0.06	6292.0	1.53	0.01
9	51	6701.0	161.00	6701.2	2.32	0.00	6701.1	2.21	0.00	6701.0	1.61	0.00
10	47	6098.6	139.00	6098.6	2.10	0.00	6098.8	2.08	0.00	6098.6	1.55	0.00
Average	45.4	5860.2	75.72	5860.7	1.93	0.01	5861.1	1.93	0.01	5860.2	1.55	0.00

NP: Number of products; OFV: Objective function value of the Gurobi, SA, TS and GA

Table 3: Algorithm solutions for large sized problem set

		Gurobi Solution			SA Solution			TS Solution			GA Solution		
Problem No	**NP**	**MIP Solution**	**OFV**	**OG (%)**	**OFV**	**CPU Time (s)**	**%Gap**	**OFV**	**CPU Time (s)**	**%Gap**	**OFV**	**CPU Time (s)**	**%Gap**
1	96	13370.6	13984.2	4.40	13859.0	67.13	-0.90	13864.3	91.18	-0.86	13850.9	65.59	-0.95
2	84	11333.7	12478.7	9.18	12195.0	60.96	-2.27	12195.3	86.69	-2.27	12184.9	66.18	-2.35
3	134	19419.1	23014.0	15.60	21234.0	97.05	-7.73	21244.5	137.28	-7.69	21219.4	100.12	-7.80
4	98	13101.3	14900.0	12.30	14344.2	74.74	-3.73	14347.9	105.14	-3.71	14320.2	74.61	-3.89
5	125	17385.9	19698.0	11.70	19241.1	89.10	-2.32	19256.0	129.86	-2.24	19230.8	90.79	-2.37
6	147	20630.0	26890.1	23.28	23940.3	107.09	-10.97	23970.0	156.30	-10.86	23900.9	111.59	-11.12
7	163	23133.7	29747.3	22.23	26465.9	102.61	-11.03	26512.7	197.67	-10.87	26436.4	142.92	-11.13
8	168	24549.4	32219.8	23.81	28462.8	130.52	-11.66	28528.1	212.43	-11.46	28420.6	118.44	-11.79
9	165	25088.2	29594.4	15.20	27953.4	132.36	-5.55	28002.9	214.44	-5.38	27912.1	142.96	-5.68
10	140	19724.8	24111.6	18.19	23402.7	107.60	-2.94	23439.5	177.95	-2.79	23390.1	116.05	-2.99
Average	132	18773.7	22663.8	15.59	21109.8	96.92	-5.91	21136.1	150.89	-5.81	21086.6	102.93	-6.01

NP: Number of products; OFV: Objective function value of the Gurobi, SA, TS and GA
MIP: Mixed integer programming best bound solution; OG: Optimality gap

For the small sized problem set, the results show that SA, TS and GA could find optimal solution for most of the problems. When the results are compared with the Gurobi solutions, it can be seen from the Table 2 that each meta-heuristic algorithm could reach to solution in very short computational times. Although, the average gaps of the algorithms are close to each other, the average computational time of GA is better than other two meta-heuristics. Moreover, the GA could reach to optimum solution for whole problem set except one instance while the SA and TS could find the solution with an optimality gap for some of the problems.

For the large sized problems, the GA exhibits the best performance and finds a better result than the SA and TS for each instance. Also, the GA provides 6.01% cost savings on objective function value of the instances according to the best integer solution of Gurobi. On the basis of computational times, each algorithm represents similar performance where the average CPU times are 96.92 *s* for SA, 150.89 *s* for TS and 102.93 *s* for GA.

In addition to comparisons of the three algorithms with respect to their solutions, a statistical analysis for the solutions are conducted by applying paired-*t* test at significance level $\alpha = 0.05$ to reveal whether there exist significant differences between any pair of meta-heuristic algorithms in terms of the solution quality. Therefore, the null hypothesis is formed between two meta-heuristic algorithms as $H_0 : \mu_{Algorithm1} - \mu_{Algorithm2} = 0$ and two sided alternative hypothesis as $H_1 : \mu_{Algorithm1} - \mu_{Algorithm2} \neq 0$, where $\mu_{Algorithm1}$ and $\mu_{Algorithm2}$ represents the population mean of the algorithm solutions. Table 4 represents the result of the paired-*t* test which carried out for both small sized and large sized instances. The test results of the small sized instances show that the GA solutions are significantly different from the SA. For the large sized instances, the GA solutions are significantly different from both of the SA and TS. As a result of the paired-*t* test, the GA outperforms the SA and TS. Also, the SA solutions are better than the TS solutions for large sized problems.

Table 4: Results of the paired-*t* test

Problem Set	Algorithm Pairs	Mean of the Difference	Standard Deviation of the Difference	*t* Value	*p* Value	Significance
Small Sized Problems	SA-TS	-0.40	1.04	-1.20	0.260773	-
	SA-GA	0.50	0.55	2.90	0.017595	GA
	TS-GA	0.90	1.39	2.04	0.071765	-
Large Sized Problems	SA-TS	-26.29	21.45	-3.88	0.003731	SA
	SA-GA	23.20	32.66	5.55	0.000356	GA
	TS-GA	49.49	32.66	4.79	0.000987	GA

5. Conclusion

This paper addresses the truck-door assignment and product placement problem in cross-docking centers and proposes SA, TS and GA to solve large sized problems. The considered problem consist of two main operational decision plans of cross-docking system: Assignment plans of the incoming trucks and outgoing trucks to doors, and product assignment plans of the products to shelves for temporary storage. The aim of the study is to find best truck-door assignment and product placement plan that minimize total travelling distance of products. In order to test the performance of the proposed algorithms several different sized problems are randomly generated by using a real-life data of a logistics company. The algorithm solutions are compared with each other on the basis of solution quality and computational times. Moreover, the proposed algorithms are statistically analyzed by using paired-*t* test to reveal whether there exist significant differences between any pair of meta-heuristic algorithms in terms of the solution quality. The results of the computational studies show GA exhibits the best performance and outperforms both of the SA and TS. Also, it is observed from the large sized problem solutions that the SA is capable to find better solution than the TS. As a result, the proposed GA can be effectively applied for the large sized real-life cross-docking systems to find efficient truck-door assignment and product placement plans.

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Integrated Consumption and Provision Map Implementation in Healthcare Sector

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Abstract

Healthcare organizations are under a big pressure to improve with the increasing life time. Patients are getting in trouble with care processes due to waste and deviations in health care services. The main idea in lean philosophy is to focus on creating customer value through eliminating wastes. After the automative industry success, other manufacturing industries and also service sector started to use lean techniques. The aim of this research is to identify actual value stream maps (VSM) via genchi gembutsu (go and see at gemba (the real place)) in health care services. The process is analyzed from the patient and service provider perspectives simultaneously in lean consumption context. "Integrated Consumption and Provision Map" is generated near VSM. In light of process analysis and VSM, "Process Mapping" technique, a detailed VSM tool, is suggested to be the first phase in patient consumption analysis. Research area is Eskisehir Yunus Emre Public Hospital Physical Therapy and Rehabilitation Service. As patient family the patients who are decided to get physical therapy after examination are selected because of the long waiting times (3 months to start therapy after examination). As a result, it is determined that patients spent 149 minutes and service providers spent 102 minutes in 14 steps process. It is emerged that lean techniques implementation will be useful to develop future VSM, taking into consideration that only 75 minutes part of the whole service is value added.

Keywords

Lean thinking, healthcare services, lean consumption, integrated consumption and provision map, value stream mapping

1. Introduction

Healthcare sector, a kind of service sector, is a valuable area for production management research with high level variability, lack of standardization and need for process flexibility (Meredith,2011). Modern hospital's complexity making management of processes and value streams difficult (Graban,2011). Patients are getting in trouble with care processes due to waste and deviations in health care services. Although patients feel uncomfortable with these problems, service providers don't investigate these cases in detail. Patients stay for long times in processes; for short time value added care services. Waste, the main component of lean thinking, is a cost increasing factor in healthcare sector. Researches showed that the waste ratio is between 30-70% in healthcare (Armstrong, 2010). Healthcare organizations are under a big pressure to improve with the increasing in life time (Poksinska, 2010). In this context the benefits of lean thinking implementation in healthcare sector are shown in the literature (Graban,2011; Mazzocato et al. 2010, Brandao de Souza, 2009; Burgess&Radnor, 2013; Plytiuk et al. 2012; Poksinska, 2010; Seddon, 2009). Hernandez (2010) defines healthcare sector as "new frontiers" for system engineering. In spite of increasing popularity in lean healthcare, applicability and advantages haven't shown exactly yet (Mazzocato et al. 2010). Multiple stakeholders and unique problems are some of the reasons.

Womack&Jones are leading researchers in lean thinking. They define the hospitals as a world consisting of unrelated processes and waiting (Womack&Jones, 2010). They wrote the main books in this area. In their last book, "Lean Solutions", they started to use "lean provision" instead of "lean manufacturing" to cover all stakeholders to produce lean solutions together in a win-win-win system. In addition to, the principles of "lean consumption" are expressed. They serve "integrated consumption and provision map" as a new tool to look the whole system with both perspectives at a glance. There are a lot of lean tools that can be used to make systems lean in a holistic way. Mapping the system is the first and probably the most important stage of the process. The decision of which lean techniques should be used can be taken only after the defining actual value streams.

To the best of our knowledge this is the first article written about lean comsumption implementation in the literature. In this study it is aimed to search lean solutions applicability for healthcare sector. It is also meaningful that research area is a kind of service sector, because of the concurrent production and consumption. Lean production and lean consumption concepts are studied simultaneously in a public hospital in Eskisehir, Turkey. As a pilot study Physical Theraphy and Rehabilitation Unit was selected.

The remainder of this paper is organized as follows: The current section gives an introductory information. A theoretical framework with an overview on lean health is presented in Section 2. Section 3 provides a literature review on lean health implementations. Case study about lean implementation is in the Section 4. Finally Section 5 discusses the results and presents conclusion, limitations, and recommendations for future studies.

2. Theoretical Framework

The origin of lean thinking is "Toyota Production System (TPS)" generated by Eiji Toyoda and Taichi Ohno in 1950's after the World War II. Ohno suggested "flow economy" instead of "scale economy". He thought that the "unit price is cheaper in mass production" idea is false and scale economy causes waste (Seddon, 2009). Lean manufacturing combines the advantages of craft and mass production. The most noteworthy difference between lean and mass production is the goal, "excellence" vs "satisfactorily good" respectively (Womack et al., 1990). Gunasekaran&Ngai (2012) indicates that "lean manufacturing" is a technique that can be applied in paradigm shift from mass production to mass customization.

2.1. Three M's

Muda, muri and mura, Japanese words, are the core concepts in lean thinking. Muda (waste), defines activities that use sources but don't create value (Womack ve Jones, 2010). Muri is used for overburden and mura is used for unevenness or inconsistency (Graban, 2011). Practitioners focus on "muda" generally because it is easy to define and eliminate. Liker (2004) call attention that people and operations systems can suffer from this misunderstanding- e.g. acitivites that eliminates muda can cause muri and there will be a misperception about lean. He stresses to analyse muda, muri and mura together as a solution.

2.2. Seven Wastes

Shiego Shingo defines "Seven Wastes" as a part of TPS (Hines, 2002): Transportation, inventory, motion, waiting, over-processing, over-production and defects. There are some wastes that suggested by researchers. Liker suggested "talent waste" as a new waste (Graban, 2011). Womack&Jones suggested "good and services that doesn't satisfy customer needs" (2010 a) and "blaming people instead of processes" (2010 b). They also define it will be a waste if the company "correctly provide wrong goods/services". Seddon (2009) proposed that "failure demand" is the biggest waste in relational marketing.

2.3. Five Basic Principles

Value, value stream, flow, pull and perfection are the five basic principles that are at the root of lean thinking (Womack ve Jones, 2010). It is very important that "customer value" concept is at the heart of the lean (Radnor ve Osborne, 2013). There are three kinds of activities in value stream analysis (Womack ve Jones, 2010): value adding, non-value adding and non-value adding but required. Activity ratios in service sector are 2%, 49%, 49% respectively (Hines, 2002). Hines (2002) describes "future value adding" activities as a fourth group. This categorization is important to decide activities. Value adding and non-value adding but required acitivities should be examined and improved; non-value adding activities should be eliminated.

2.4. Lean Consumption

Womack ve Jones (2010 b) started to use "lean consumption" instead of "lean manufacturing" to emphasize the consumption process that suppliers, workers, consumers can develop lean solutions together in a win-win-win system. They investigate lean consumption in "Lean Solutions (2005)" book in detail. These are the basic six principles of lean consumption:

a. Solve the customer's problem completely.
b. Don't waste the time.
c. Provide exactly what the customer wants.
d. Provide value where it's wanted.
e. Provide value when it's wanted.
f. Continually aggregate solutions to reduce the customer's time.

2.5. Lean Health

Womack&Jones (2010) define hospitals as a world contains disconnected processes and waitings. Treatment time is only a short time in total time. Poksinska (2010) states that a patient can wait hours for only 10 minutes examination. Because of this reality patients are really "patient (tolerant)". Graban (2011) is a leading researcher in lean healthcare. He indicates that lean technique's success is proven in service sector including healthcare service. Mazzacato et. al. (2010) drew a conclusion that lean can be impemented in healthcare sector succesfully after the critical analysis of 33 articles written between 1998-2008. Plytiuk (2012) call attention that there is an increase in lean health implementations after 2009 generally in United States and United Kingdom. Table.1. show that some of the research informations are collected from Güleryüz (2012), Castle (2008), Doğan (2011), Ozdemir (2013), Efe (2011) and Yüksel (2012).

To be "a new movement" or a "management fashion" is not the reason. Sustainable results are the reason of this success (Brandao de Souza, 2009). Zero defect, continous improvement and focusing on just in time production are the enabling factors in health care systems (Kollberg, 2006). Graban (2011) indicates that some hospitals started to test lean techniques in 1990's. Royal Bolton and Virginia Mason are the hospitals that implemented lean in healthcare in a holistic approach (Radnor ve Osborne, 2013). Lawal et al. (2014) asserted that Virginia Mason Hospital applications had a catalyst effect in lean health. Some of the gainings after 3 years implementation can be summarized as follows (Yuksel, 2012):

- 53% decrease in inventory level
- 36% increase in efficiency
- 41% decrease in space requirement
- 65% decrease in provision time
- 44 % decrease in human movements.
- 82% decrease in set-up times

Laboratories are the first implementation areas of lean in hospitals because of the similarity with production lines (Yüksel, 2012). It can be seen that emergency services are the most popular research areas in lean health implementations (Mazzacato et. al. 2010). Aytac (2009) and Ozdemir (2013) made thesis on lean implementation in physical therapy and rehabilitation in Turkey universities but it couldn't find any international article. Toussaint ve Gerard (2010) adjusted the five basic principles of lean for healthcare: focus on patient, define value for patient, eliminate all other wastes and minimize the examination time (Burgess, 2013). Poksinska (2010) indicates that "value stream" and "continous flow" principles fight with "silo effect" and summarizes the difficulties in lean health implementation as follows: Personel persuasion, education, deficiency in focusing on patient, organizational structure, coordination with other departments.

3. Lean Techniques

Lean tehcniques should be percepted as a philosophy and techniques in lean toolbox should be used in a holistic view. There are a lot of lean techniques in literature. Their names are generally Japanese. Mapping tools (e.g.value stream mapping (VSM)), heijunka, standardized work, visual management, 5S, just in time (JIT), jishuken, cellular manufacturing, yamazumi, shojinka, SMED, jidoka, poka yoke, andon, total productive maintanance, kaizen and kaikau, genchi gembutsu, A3, harada, oobeya, hoshin kanri are some of the lean techniques. Genchi gembutsu and VSM are the lean tools used in this study context. "Process Mapping" based "Integrated Consumption And Provision Map" techniques are the tools used in the VSM, 2nd step current state mapping.

3.1. Genchi gembutsu

There are three types of process in an organization: existing process, process in manager's mind and expected process. Lean thinking stress that managers should go to gemba (where the work is done exactly) to see what is the existing process really and define the wastes (Graban, 2011). The core lean concept "value" can only be generated in gemba (Womack ve Jones, 2010 b).

3.2. Value Stream Mapping (VSM)

Value stream mapping (VSM) is the commonly used lean technique (Poksinska, 2010). "Material and Information Flow Mapping" technique in Toyota is the origin of VSM. Current and future states of the system can be visualized by VSM in lean implementations. VSM is a systematic process consists of four steps (Rother ve Shook, 1999): Define product family, document current state, design future state and develop an implementation plan to attain future state.

Table 1: Some of the Lean Health Implementations About Mapping

	Researcher	Year	Service	Technique	Output
1	Black ve Miller	2008	Oncology	VSM, 5S, Work Flow Mapping	14% decrease in waiting time, 57% increase in patient number, 61% decrease in personel walking
2	Castle	2008	Operating theatre Emergency service Pharmacy Sterilization Ophtalmology Outpatient	Gemba	Decrease in patient waiting time
3	Dickson vd.	2008	Emergency service	Gemba, Kaizen, VSM, standardized work, process re-design,	9,23% increase in patient number, process time decreased, patient and personel satisfsction increased, 8.1% decrease in flow time
4	Gran ve Wilcox	2008	Emergency service	Process mapping	Bed waiting time decreased from 4,5 to 2,5 hours
5	Hirst ve Weimer	2008	Cardiology	Process mapping	40% decrease in process time
6	Fosdick ve Uphoff	2007	Sterilization, Operating theatre Laboratory	Walking and working area design, process re-design	Bottleneck destruction, reduction in walking time, and 20% decrease in blood count
7	Graban	2007	Laboratory	Process re-design, 5S, visual management, standardized work, visual control, kanban	Improvement in sample, personel and material flow
8	Kim vd.	2007	Radiation oncology	VSM, single piece flow	Steps decreased from 27 to 16 steps in process, time decreased from 290 to 225 minutes, treatment start time decreased from 1 week to 1 day
9	Lewis	2007	Ophtalmology (catarakt unit)	VSM	Steps decreased from 42 to 35 steps in process, waiting time decreased from 25 weeks to 10 weeks
10	Jones ve Mitchell	2006	Emergency service	VSM	25% decrease in patient waiting time, decrease in workload
11	King vd.	2006	Emergency service	VSM	Decrease in patient waiting time

3.3. Integrated Consumption and Provision Map

Womack ve Jones (2010 b) indicate that visual materials are more useful that verbal materials for managers and introduce a new lean mapping tool in lean consumption context called "Integrated Consumption and Provision Map" in their last book "Lean Solutions". "Lean Consumption" and "Lean Provision" maps are drawn simultaneously to see the process in holistic way from both perspectives (Womack ve Jones, 2010 b). It is an integration of two maps, to see what is happening from the customer and supplier view at the same time.

4. Case Study

To imitate Toyota tools is not being lean. Ohno indicates that TPS was developed based on necessities. He suggests people who want to become lean to state necessities precisely and make developments for these identical situations (Liker, 2004). According to these suggestions, a lean implementation was carried out in Yunus Emre Public Hospital (YEPH) Pyhsical Teraphy and Rehabilitation Unit (PTRU) in Eskisehir to improve productivity in this study. YEPH serves health service with 334 bed capacity in 57.000 m^2 space. There are approximately 200 physician in 34 different service.

4.1. Observation (Genchi Gembutsu)

In the first part of the study data was collected via observation. For this purpose, researcher made observations in the gemba (the area in which service ise rendered actually) according to Ohno's suggestions. Outpatient waiting area, polyclinic, PTRU waiting area, PTRU service area and theraphy cabin are the gemba points. It is the lean technique called genchi gembutsu, to see the work in gemba. Observation times are determined to see the process in different times during a service day. There was no interaction between researcher and people in this shadowing process (Casey, 2007). Collected data ise used to draw process diagrams in the next step of the study.

4.2. Value Stream Mapping (VSM)

4.2.1. Drawing process diagrams

Process diagrams were generated including all patient families to take an x ray of the system. In the health care terminology "taking x ray" was used to lighten the system as black box. At this stage it is aimed to see whole process beginning from the entrance of the patient to PTRU polyclinic to the last session of the therapy. Four detailed process diagrams are the source of the maps generated in lean implementation. This step can be seen as an initial step for VSM.

4.2.1. Determining Patient Family

In the 1st step of VSM, six patient families determined in PTRU that can be seen Table.2. Patient family 2 selected in this study because of the late appointment times nearly 3 months for Pyhsical Therapy/Rehabilitation sessions. Phsicians decide these patients to get at least 10 at most 20 session physical therapy and rehabilitation. This situation causes bottleneck in the service system. Also lean studies generally made in polyclinics (outpatient) equivalent to patient family 1. This study can be seen as a pilot study. Lean implementation can be enlarged to the other services (laboratory, radiology etc.) and the other patient families can be investigated in the future.

4.2.3. Current Value Stream Mapping

After the genchi gembutsu and drawing process diagrams, current Value Stream Map was drawn (Figure.1) After this, patient consumption process was analysed. Patient consumption process was analysed with two stages. In the first stage "Process Mapping" technique suggested by Hines(2002) was adopted to analyze the map in detail. In this context all action steps were listed in the process and examined whether they are value-adding or non-value adding activities by genchi gembutsu and talking with nurses and patients. This examination can be seen in Table.3. In the second stage "Patient Action Steps" (Table.4) and "Service Provider Action Steps" (Table.5) were listed to be base for "Integrated Consumption and Provision Map". It can be seen that patient spent 75 minutes value-adding and totaly 149 minutes time to get the health service in 14 steps. However service provider spent 102 minutes to give this service in 14 steps. Boxes-drawn from left to right- in this map represent the individual actions in whole process. Box lenghts are proportional with the time required for that action. Value-added actions are shaded to stress. Dashed lines represent the appointment activity. "Integrated Consumption and Provision Map" can be seen in the Figure 2.

5. Conclusion

In this study a lean implementation was started in Yunus Emre Public Hospital Physical and Therapy Unit. Genchi gembutsu, value stream mapping, process diagram drawing, process mapping and integrated consumption and provision mapping techniques were used in this concept. To the best of our knowledge it is the first study that used "Integrated Consumption and Provision Map" with VSM and "process mapping". Current condition of the system analyzed with different kinds of mapping techniques together.

Table.2. Patient Families

Patient Family No	Action Sequence
1	Examination
2	Examination +Pyhsical Therapy/Rehabilitation
3	Examination + Hospital Stay
4	Examination +Laboratory/Radiology+Results
5	Examination + Laboratory/Radiology + Results + Pyhsical Therapy/Rehabilitation
6	Examination + Laboratory/Radiology + Results + Hospital Stay

As a result, it is determined that patients spent 149 minutes and service providers spent 102 minutes in 14 steps process. It is emerged that lean techniques implementation will be useful to develop future VSM, taking into consideration that only 75 minutes part of the whole service is value added. There can be observational and data collecting limitations in this study. Also this study is a pilot study conducted for a starting point. There needs to use lean techniques (decided to eliminate detected mura, muri and muda) to reach future value stream maps.

Result generalization can't be possible for the other services in the hospital because of the special characteristics of the services. By the way the results will be useful to stress the waiting times and show the both perspectives together. In the future studies the patient families will be enlarged to contain radiology and laboratory units to reach the global optimum instead of local optimum. Long term data will be useful to analyse the system in detail. This research can be carried on private and university hospitals. It shouldn't be overlooked that lean implementation is a prolonged process nearly 5 years. It will be useful to make hospital-academician colloboration to make health service process efficient.

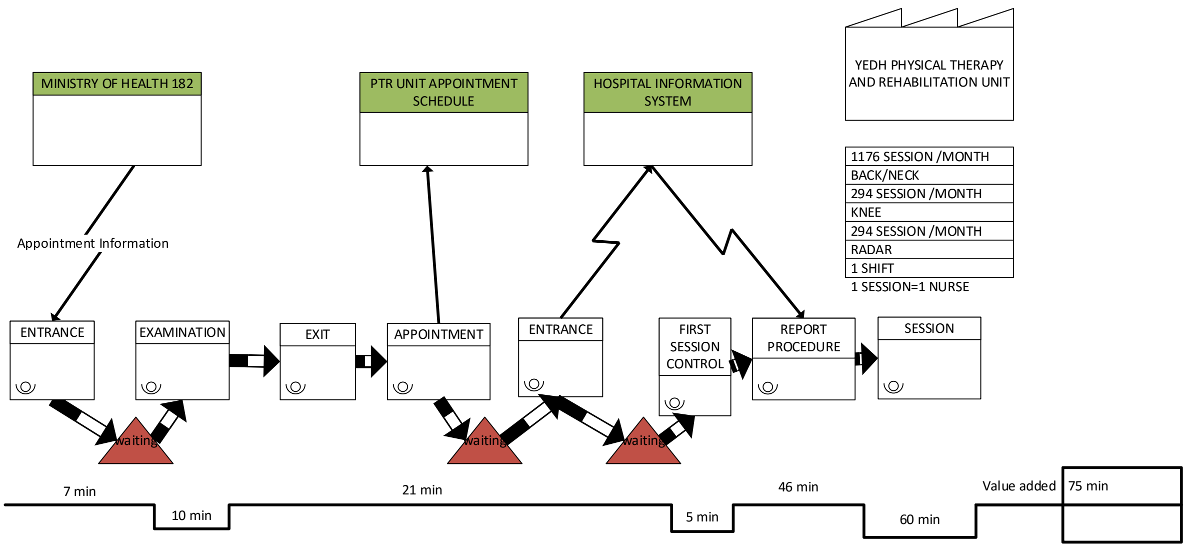

Figure 1: Current Value Stream Map

Table.3. Process Mapping adopted from Hines (2002)

No	Unit	Action Step	Time (min.)	Concerning Personel	Action Type		
					Value adding	Non-value adding	Non-value adding-required
1	PTR Polyclinic	Entrance procedure	2	Polyclinic Secretary			√
2		Waiting	5	-		√	
3		Examination	10	Physician	√		
4		Exit procedure	2	Poly. Secr.		√	
5	PTR Unit	Appointment procedure	5	Unit Secr.			√
		Waiting*	148320	-		√	
6		First session Entrance procedure	2	Unit Secr.			√
7	PTR Polyclinic	Entrance procedure	2	Poly. Secr.			√
8		Waiting	10	-		√	
9		Examination	5	Physician	√		
10	**PTR Unit**	First session Report procedure	5	Unit Secr.			√
11	**Physician**	Physician approval of the report	10	Physician		√	
12	**Medical Superintendent (MS)**	Medical Superintendent (MS) approval of the report	30	MS Affirmative Authority		√	
13	PTR Unit**	Session entrance	1				√
14		Treatment	60	Nurse	√		
		Waiting***	1440	-			√
		Total Time Spent By Patient (min):			149		
		Value-adding Time(min):			75		
		Total Step Number:			14		

*It is planned to use lean techniques to shorten this waiting time. This time is ignored in this step analysis.
**These three steps are continuing during until the session.
***This time is non-value adding but required because there can be only a session in one day. Patient should wait one day to get the other session. This time is ignored in this step analysis.

Table.4. Patient Action Steps

No	Action Step	Time (minute)
1	Entrance procedure	2
2	Waiting	5
3	Examination	10
4	Exit procedure	2
5	Appointment procedure	5
6	First session Entrance procedure	2
7	Entrance procedure	2
8	Waiting	10
9	Examination	5
10	First session Report procedure	5
11	Physician approval of the report	10
12	Medical Superintendent (MS) approval	30
13	Session entrance procedure	1
14	Getting Treatment	60
	Total Time Spent By Patient (min):	149
	Value-adding Time(min):	75
	Total Step Number:	14

Table.5. Service Provider Steps

No	Action Step	Time (minute)
1	Entrance procedure	2
2	Examination	10
3	Exit procedure	2
4	Appointment procedure	5
5	Session Control Table Filing	3
6	First session Entrance procedure	2
7	Entrance procedure	2
8	Examination	5
9	First session Report procedure	5
10	Physician approval of the report	1
11	Medical Superintendent (MS) approval	2
12	Session entrance procedure	1
13	Giving Treatment	60
14	Recording the Session Information	2
	Total Time Spent By Service Provider:	102
	Value-adding Time:	75
	Total Step Number:	14

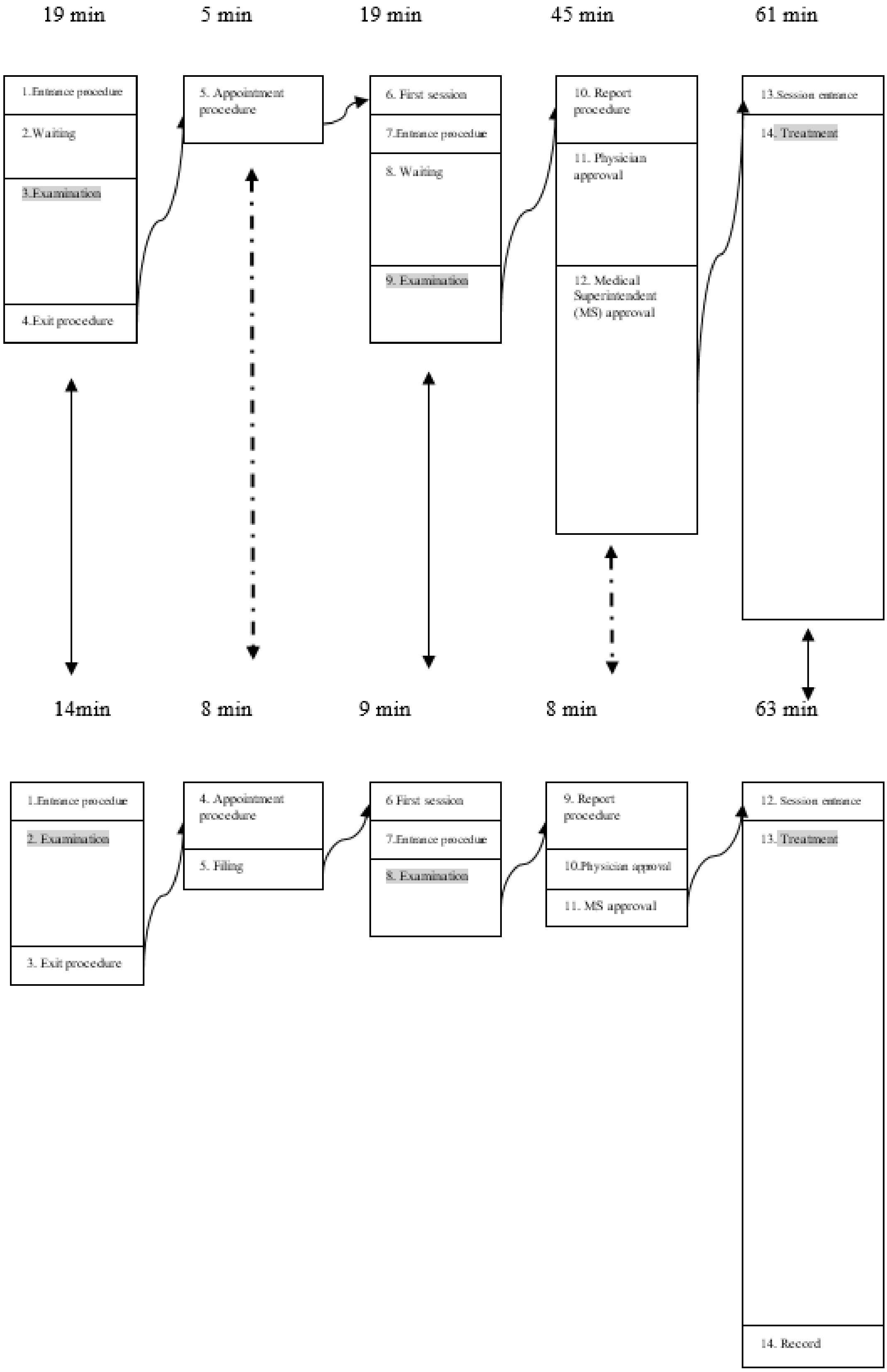

Figure 2: Integrated Consumption and Provision Map adopted from Womack&Jones(2005)

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Reliability analysis of product fleets in use phase: Risk detection and prognosis based on data logger

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The increasing complexity of product functionality and manufacturing process parameters often leads to complex failure modes and reliability problems within the product life cycle. Especially in the case of mass production of consumer goods - e.g. automobiles, washing machines, computers - an increasing percentage of damaged products within the product fleet can lead to garage or recall actions. If the manufacturer gets knowledge about the first damage claims based on a field observation, a risk probability prognosis regarding the whole product fleet (population) is the base of operations regarding further actions. State of the art risk calculation methods, e.g. Kaplan-Maier estimator or Eckel-candidate method, are considering the failure behaviour (point of failure appearance) and allow the univariate determination of the risk probability regarding the product fleet based on one life span variable (e.g. switching cycles). These methods are not considering a multivariate load/usage profile of the products based on different life span variables. In fact, actual technical complex products save a lot of life data ("Big Data") in electronic control units, which can be additional used for risk analysis within product fleets. This contribution outlines an approach to determine the risk probability in product fleets based on a combined multivariate analysis of the product failure behaviour and the customer product usage profile. The base of operations is a sample of damaged products; the damage data are known. The goal of the multivariate risk analysis is the determination of candidates within the product fleet, which are at risk. Furthermore the risk analysis should include a time related prediction, when the candidates will appear as damage cases. The approach contains five steps: 1) Technical analysis of life span variables, 2) Cluster analysis to find damage descriptive life span variables, 3) Cluster analyses to detect candidate areas at risk within the product fleet, 4) Reliability and risk prognosis. The theory and application of the approach is explained based on a synthetic data set within an automotive case study, which includes real effects of typical field failure behaviour and the usage profile of an automobile fleet. The results and messages are transferable to other industrial and consumer products.

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Biography

Stefan Bracke is Professor at the University Wuppertal and leads the Chair of Reliability Engineering and Risk Analytics since 2010. Furthermore he is a guest professor at Meiji University, Department of Mechanical Engineering Informatics Meiji University, Kawasaki, Japan. The focus of his research work are product and process reliability and risk analytics. He studied mechanical engineering at the University of Bochum in Germany (1991 – 1995). In 1996 to 1999 he was a scientific assistant at the chair of manufacturing system planning at the University of Bochum, Germany. Stefan Bracke finished his research work in 1999 with the doctoral thesis in quality strategies for remanufacturing. 2000 – 2006 he worked as a quality engineer (reliability methods and planning) at the Porsche Company (Stuttgart, Germany). 2007 – 2010, Stefan Bracke was Professor at the Cologne University of Applied Sciences and led the department of quality management and production metrology.

A particle swarm optimization algorithm for integrated forward-reverse supply chain network decisions

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Supply chains are traditionally characterized as forward flow of materials from origin to consumption locations. To encompass whole life cycle of a product, including end-of-life phase, integrated supply chain framework including both forward and reverse flows of a product can be constituted. In supply chain management, network decisions are of strategic level decisions for performance of a chain in long term. Network decisions regarding integrated forward-reverse supply chains are generally composed of design and planning decisions. While the design decisions refer determining number, location, type or capacity of forward and reverse flow facilities simultaneously, the planning decisions state assigning appropriate material flow between each pair of facilities in the integrated network. Considering that network design and planning problem in integrated forward-reverse supply chains is NP-hard, effective solution approaches should be developed for integrated forward-reverse supply chain network design and planning.

The scope of this study is to develop a particle swarm optimization algorithm for integrated forward-reverse supply chain network decisions. In the proposed algorithm, candidate solutions are represented with priority based encoding. The algorithm determines the configuration of the integrated supply chain network and material flow assignment between network stages in terms of profit maximization. Numerical experiments are performed in order to validate the proposed algorithm and a hypothetical example is presented for illustration. Achieved results showed the performance and applicability of the proposed algorithm.

Biography

Seval Ene is a research assistant in the Industrial Engineering Department of Uludag University, Turkey. She received her BS, MS and PhD from Uludag University, in 2007, 2010 and 2015, respectively, all in industrial engineering. Her research interests include logistics and supply chain management, reverse and closed loop supply chains, green logistics, optimization, mathematical modelling and heuristics algorithms.

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Network design for closed loop supply chains using multi-objective optimization model

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In recent years, environmental issues have been gaining growing interest in several research areas. Closed loop supply chains are one of these intersection areas which associates supply chain management and environmental issues. In a closed loop supply chain, bi-directional material flows, named as forward and reverse flows, are considered simultaneously. Reverse supply chain is a series of activities to collect end-of-life products from customers and recover value of them with appropriate recovery options (reuse, remanufacturing, refurbishment, recycling etc.) or dispose of them. With integrating reverse flows of end-of-life products to the classical forward supply chain a closed form of supply chain is founded. Managing entire of forward and reverse supply chain activities efficiently requires establishing an appropriate logistics infrastructure and well-designed network structure. Network design is the problem of determining number and location of facilities and assigning amount of materials to transport between these facilities.

This study addresses the problem of closed loop supply chain network design. A multi-objective optimization model is developed to obtain optimum structure of the closed loop supply chain considering economical and environmental objectives. Carbon footprint and environmental impact minimization objectives and total profit maximization objectives are considered in the modeling framework of the closed loop supply chain network. Numerical experiments are performed to validate the proposed model and to analyze tradeoffs between economical and environmental objectives.

Biography

Seval Ene is a research assistant in the Industrial Engineering Department of Uludag University, Turkey. She received her BS, MS and PhD from Uludag University, in 2007, 2010 and 2015, respectively, all in industrial engineering. Her research interests include logistics and supply chain management, reverse and closed loop supply chains, green logistics, optimization, mathematical modelling and heuristics algorithms.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A Decomposition Method to Solve a Game Based Multi-objective Model for a Scheduling Problem at a Chemotherapy Center under Uncertainty

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Abstract

This paper aims at improving the quality of service in the oncology centers. For this purpose, the scheduling of chemotherapy is considered in this research. A mix integer programming model as a bi-level bi-objective model is developed to schedule the patients at chemotherapy centers. Due to uncertainty parameters in the real world, a fuzzy approach is applied. Based on the scheduling model, the patients are sequenced or assigned to resources at each day by the scheduling model. Its upper-level objective minimizes the completion time of all treatments. Meanwhile, the lower-level objective minimizes the completion time of each facility and staffs at each day. A Benders decomposition method is developed to solve the presented mathematical model. Empirical data are collected from the chemotherapy center in Tehran, Iran to illustrate the validation and the application of our model. The associated results of our presented model are very promising compared to the First-Come-First-Serve (FCFS) policy. Moreover, the results show that our model is more effective to improve the quality of treatment in chemotherapy centers.

Keywords

Game theory, chemotherapy, scheduling; uncertainty, benders decomposition.

1. Introduction

Cancer is a term used for diseases characterized by abnormal or out-of-control cell growth. Cells are the body's basic unit of life that is the place for all cancers begin. Most cancers are classified by the organ or kind of cell in which they start, so more than 100 various types of cancer are diagnosed. One of the most common cancer treatment therapies is chemotherapy that uses drugs to kill cancer cells. There are various drugs that have different treatment ways to stop the growth of cancer cells (Barton-Burke et al., 2001). Due to increasing population, successful treatment, the age-sensitive nature of cancer, and increasing aging population the demand for oncology services is predicted to increase up to 61 million in 2020 (Erikson et al., 2007). Improved managements of side effects and progress methods for treatment are increasing the demand for oncology services, and chemotherapy is in front of the massive workloads that can result in laboratory, pharmacy, and chemotherapy administration delays (Aboumater et al., 2008). The highest priorities for improving the healthcare system, especially chemotherapy center, because Stuckless et al. (2012) indicated that this growing demand is not matched by increasing in the facilities, number of oncologists and specialist nurses. On the other side, delays and disruption in the procedure of the cancer treatment can have great negative effects on a patient health and life expectancy (Athawale, 2015). A center must reduce waiting time to treat more patients and reduce costs of clinic that need to remove unnecessary and inadvertent overheads in the clinic, improve procedures for the organization, and maximize utilization clinic resources (Gesell & Gregory, 2004). In previous studied, Clinic resources like an oncologist, nurse staffing, bed or chair, and nursing care requirements have not applied for schedule clinic (Chabot & Fox, 2005) and most authors consider just nursing or pharmacy time to schedule (Hawley & Carter, 2009).

This research proposes the scheduling models for chemotherapy planning by considering limited clinical resources. Moreover, the several stages of the chemotherapy center are considered in this model. The scheduling model is formulated under the uncertain environment by using a fuzzy programming approach. The scheduling models are developed as a bi-level bi-objective problem. The scheduling model sequences or assigns the patients to the available resources at each day for all stages of the chemotherapy center. Its upper-level objective (leader’s objective) of the scheduling model minimizes the completion time of all treatments. Moreover, its lower-level objective (follower’s objective) minimizes the completion time of each facility and staffs at each day. To solve the bi-level model, a game based Benders decomposition algorithm is applied. In addition, the simulation model based on the real case is developed for comparison between the proposed models and the real system. Some test problems based on an empirical data from a chemotherapy center are developed to illustrate the validation and application of our model. The rest of the paper is structured as follows. Section 2 provides a literature review in the scheduling chemotherapy center. Section 3 describes the characteristics of the chemotherapy scheduling problem. Section 4 presents a mathematical programming model and Section 5 describes a solution methodology to solve the proposed model. Computational results are given in Section 6 to show the effectiveness of the proposed model. Finally, Section 7 summarizes the conclusion and expresses possible extensions.

2. Literature Review

According to the literature review, there are two approaches, namely, functional care delivery models and primary care delivery models to formulate the resources assigning problem and scheduling problem in oncology centers. Various resources (e.g., nurse and oncologist) are assigned to the various patients at each day of the planning horizon by the functional care delivery models (Ireland et al., 2004). The primary care delivery models assign each patient to a primary resource at each visit (Ireland et al., 2004). In this research, the functional care delivery models are applied to formulate the concerned problem. Ireland et al. (2004) and Liang and Turkcan 2015 present that the functional care delivery models are applied in 40% of cases and the primary care delivery models are applied in 30% of cases in oncology clinics. Some researches solved the chemotherapy scheduling problem as nurse scheduling problems (Hawley & Carter, 2009). Chabot and Fox (2005) classified the patients systematically and applied the scheduling and planning models to model. Sevinc et al. (2013) developed a two-phase approach to solve the chemotherapy planning and scheduling problem. In the first phase, an adaptive negative-feedback scheduling algorithm is applied and then two heuristic algorithms based on the 'Multiple Knapsack Problem' applied to assign patients to infusion seats. A multi-criteria optimization problem is established by Condotta and Shakhlevich (2014) to book the chemotherapy appointments. A multi-objective optimization model is developed by Petrovic et al. (2011) to schedule radiotherapy appointments at Arden Cancer Centre in the UK. Gocgun and Puterman (2014) proposed the Markov decision process as a novel technique for chemotherapy planning and scheduling at the British Columbia Cancer Agency in Canada. Hahn-Goldberg et al. (2014) considered an uncertainty in the outpatient scheduling problem at the chemotherapy. Legrain et al. (2014) developed an integrated hybrid method, namely, stochastic optimization and online optimization, to plan the oncology cancer.

Le et al. (2015) applied the greedy algorithm and the Tabu search algorithm to schedule an appointment patient at the oncology center of a hospital. Cao and Lim (2011) formulated a procedure of the specific types of cancer treatment and used operation research techniques to increase the efficiency of the cancer treatment. Kallen et al. (2012) presented a three-part plan to minimize a patient waiting time and increase efficiency and throughout the center. Petrovski et al. (2004) applied a hybrid particle swarm optimization (PSO) and genetic algorithm (GA) algorithms to solve the scheduling of chemotherapy centers. The spreadsheet-based optimization tools are developed by Liang and Turkcan (2015) to determine the optimal decision for the scheduling of oncology clinics. Yokouchi et al. (2012) formulated a scheduling problem at the outpatient chemotherapy center as a discrete event simulation model. As another research, Woodall et al. (2013) proposed a discrete-event simulation model to evaluate the patient waiting time and resource utilization in the center institute. Santibáñez et al. (2012) focused on the appointment booking in a large cancer center in British Columbia, Canada by a discrete-event simulation method. Ma et al. (2015) investigated by the simulation and optimization models with the decision-making process at a cancer center in British Columbia. Huggins and Pérez (2014) formulated scheduling and planning problem in the state of Montana by considering maximizing the resource utilization and balancing the human workload as objective function. Ahmed et al. (2011) establish a scheduling template for scheduling patients and developed a simulation model to obtain the best scenario. Sadki et al. (2010b) developed an integer programming model by considering the minimizing the resource workload to schedule patients in oncology center and assign the patients to resources based on their protocols. Sadki et al. (2010a) followed the previous study and proposed the new Mixed Integer Programming (MIP) model. They applied a three-stage heuristic algorithm to solve the proposed model. As another research, Sadki et al. (2011) used a Lagrangian relaxation-based method and a local optimization method to schedule the patients at the oncology outpatient center. The acuity-based models are developed for scheduling and planning at the chemotherapy center by Turkcan et al. (2012).

To the best of our knowledge, this research is the first study that addresses the scheduling of patients in the various stages of chemotherapy (i.e. laboratory, pharmacy, oncology clinic and infusion clinics). The proposed model considers an availability of clinical resources (e.g., beds/chairs, medical rooms, nurses, pharmacists, oncologists and laboratory technicians) constraint in different stages. Moreover, the model formulated under uncertain environment. For this purpose, a hybrid fuzzy programming approach is applied. The game theory is applied to develop the scheduling model is formulated as the bi-level bi-objective model. The upper-level objective of the scheduling model is to identify the minimized completion time of all treatments. Meanwhile, its lower-level objective minimizes the completion time of each facility and staffs at each day. A game based benders decomposition algorithm is utilized to solve the proposed model and also the simulation model are presented to compare the performance of our models with the actual system.

3. Problem Description

3.1 Chemotherapy Treatment Approach

The chemotherapy is applied as the most systematic treatment to treat various cancers. The chemotherapy uses the different drugs to control the cancerous cells, stop or slow the progression of them, and relieve the cancer symptoms. The patients are treated according to the systematic procedure is called a protocol. The oncologist determines the best protocols based on the stage of cancer, type of cancer, survival rate and the patient's medical status (Ochoa et al., 2007). Each protocol contains the types of drugs, dosage, appointment time of oncologist and laboratory, length of using drugs, cycle length and the number of times to repeat this cycle. The treatment of patients without any delays during the patients' treatments is the most significant priority of chemotherapy centers.

3.2 Patient Flow in Chemotherapy Clinic

There are some researches considered a patients flow and resource constraint in the formulation of the oncology centers (i.e., Sadki et al., 2010b; Sadki et al., 2010a). The comprehensive flow of the chemotherapy patients in oncology illustrated in Figure 1 is not considered in the previous researches. Based on the registration of patients, the laboratory assistants take the clinical specimens to determine the patients' status and cancer condition. After preparation of test and laboratory result, the oncologists determine the type of cancer and stage of cancer and they prescribe the protocols for the new patients. In a pharmacy stage, the pharmacy staffs prepare the kind of drugs and their dosage based on the patient's orders. Based on the patient's protocol, the drugs are given into the bloodstream or by mouth to go through the body. An infusion lasts from 15 minutes to 7 hours or longer (Sadki et al., 2010a). At the infusion clinic, nurses perform the chemotherapy administration and control side-effects. All the producer of these stages repeat periodically in duration of patient treatment planning.

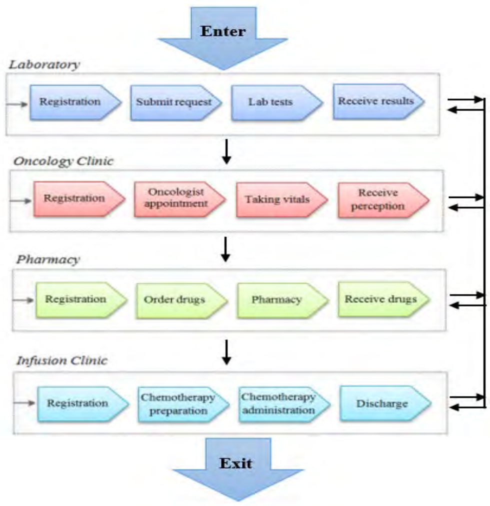

Figure 1: Patient's flow in a chemotherapy clinic

4. Mathematical Model

The comprehensive scheduling model is formulated by a bi-objective multi-objective. The leader objective function minimizes the completion time of all treatments at each day of the planning horizon. The follower objective minimizes the completion time of each facility and staffs at each day of the planning horizon. The parameters and decision variables that will be used throughout our study are represented as follows:

Sets:

P_t^l Patients are assigned to day t to start stage l of their treatment $(i = 1, \dots, P_t^l)$

T Length of planning horizon (day) $(t = 1, \dots, T)$

L Number of stages $(l = 1, \dots, L)$

N_t^l Number of staffs (nurses, oncologist, and etc.) at stage *l* of day t ($j = 1, \dots, N_t^l$)
K_t^l Number of facilities (e.g., beds, chairs and medical rooms) at stage *l* of day *t* ($k = 1, \dots, K_t^l$)

Parameters:
$\widetilde{wc}$ Cost of completion time of all treatments
$\widetilde{wp}$ Cost of completion time of all treatments assigned to the facility
$\widetilde{wm}$ Cost of completion time of all treatments assigned to the staff
$\tilde{R}_{itl}$ Treatment time that patient *i* needs on day *t* of the planning horizon
M Large number

Decision variables:
$Co_t^{l,Max}$ Maximum Completion time of all treatments at stage *l* on day *t*
C_{ijkt}^l Completion time of patient *i* assigned to staff *j* and facility *k* at stage *l* on day *t*
S_{ijkt}^l Start time of patient *i* assigned to staff *j* and facility *k* at stage *l* on day *t*
M_{jt}^l Completion time of all treatments assigned to staff *j* at stage *l* on day *t*
P_{kt}^l Completion time of all treatments assigned to facility *k* at stage *l* on day *t*
V_{ijkt}^l Binary variable, 1 if the treatment of stage l of patient *i* started by resource *k* and staff *j* at day *t*; 0, otherwise
$A_{ii'jt}^l$ Binary variable, 1 if the treatment of stage l of patient *i* is assigned to the staff *j* at day *t* earlier than treatment of stage *l* of patient *i′*
$Y_{ii'kt}^l$ Binary variable, 1 if the treatment of stage l of patient *i* is assigned to the resource *k* at day *t* earlier than treatment of stage *l* of patient *i′*

The scheduling model is represented as follows:

$$\text{Min } z_1 = \sum_{t=1}^{T}\sum_{l=1}^{L} \widetilde{wc}\; Co_t^{l,Max} \tag{1}$$

$$\text{Min } z_2 = \sum_{t=1}^{T}\sum_{l=1}^{L}\sum_{k=1}^{K_t^l} \widetilde{wp}\; P_{kt}^l + \sum_{t=1}^{T}\sum_{l=1}^{L}\sum_{j=1}^{N_t^l} \widetilde{wm}\; M_{jt}^l \tag{2}$$

s.t.

$$\sum_{j=1}^{N_t^l}\sum_{k=1}^{K_t^l} V_{ijkt}^l = 1 \qquad \forall i \in P_t^l;\ t \in T;\ l \in L \tag{3}$$

$$C_{ijkt}^l + S_{ijkt}^l \le M\,(V_{ijkt}^l) \qquad \forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L \tag{4}$$

$$C_{ijkt}^l \ge S_{ijkt}^l + \tilde{R}_{itl} - M\,(1 - V_{ijkt}^l) \qquad \forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L \tag{5}$$

$$\sum_{j=1}^{N_t^l}\sum_{k=1}^{K_t^l} S_{ijkt}^{l'} \ge \sum_{j=1}^{N_t^l}\sum_{k=1}^{K_t^l} C_{ijkt}^l \qquad \forall i \in P_t^l \cup P_t^{l'};\ t \in T;\ l, l' \in L;\ l < l' \tag{6}$$

$$\sum_{j=1}^{N_t^l} S_{ijkt}^l \ge \sum_{j=1}^{N_t^l} C_{i'jkt}^l - M\,(Y_{ii'kt}^l) \qquad \forall i \in P_t^l;\ i' \in P_t^l;\ t \in T;\ k \in K_t^l;\ l \in L \tag{7}$$

$$\sum_{j=1}^{N_t^l} S_{i'jkt}^l \ge \sum_{j=1}^{N_t^l} C_{ijkt}^l - M\,(1 - Y_{ii'kt}^l) \qquad \forall i \in P_t^l;\ i' \in P_t^l;\ t \in T;\ k \in K_t^l;\ l \in L \tag{8}$$

$$\sum_{k=1}^{K_t^l} S_{ijkt}^l \ge \sum_{k=1}^{K_t^l} C_{i'jkt}^l - M\,(A_{ii'jt}^l) \qquad \forall i \in P_t^l;\ i' \in P_t^l;\ t \in T;\ j \in N_t^l;\ l \in L \tag{9}$$

$$\sum_{k=1}^{K_t^l} S_{i'jkt}^l \ge \sum_{k=1}^{K_t^l} C_{ijkt}^l - M\,(1 - A_{ii'jt}^l) \qquad \forall i \in P_t^l;\ i' \in P_t^l;\ t \in T;\ j \in N_t^l;\ l \in L \tag{10}$$

$$C_{ijkt}^l \le Co_t^{l,\text{Max}} \qquad \forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L \tag{11}$$

$$C_{ijkt}^l \le M_{jt}^l \qquad \forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L \tag{12}$$

$$C_{ijkt}^l \le P_{kt}^l \qquad \forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L \tag{13}$$

$$V_{ijkt}^{l} \in \{0,1\} \qquad \forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L \tag{14}$$

$$Y_{ii'kt}^{l} \in \{0,1\} \qquad \forall i \in P_t^l;\ i' \in P_t^l;\ t \in T;\ k \in K_t^l;\ l \in L \tag{15}$$

$$A_{ii'jt}^{l} \in \{0,1\} \qquad \forall i \in P_t^l;\ i' \in P_t^l;\ t \in T;\ j \in N_t^l;\ l \in L \tag{16}$$

$$S_{ijkt}^{l}, C_{ijkt}^{l} \ge 0 \qquad \forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L \tag{17}$$

$$P_{kt}^{l} \ge 0 \qquad \forall\ k \in K_t^l;\ t \in T;\ l \in L \tag{18}$$

$$M_{jt}^{l} \ge 0 \qquad \forall\ j \in N_t^l;\ t \in T;\ l \in L \tag{19}$$

$$Co_t^{l,\mathrm{Max}} \ge 0 \qquad \forall\ t \in T;\ l \in L \tag{20}$$

Each patient who stage l of his/her treatment must be done at day t (i.e., i ∈ P_t^l) is assigned to at most one resource and one staff by Constraint (3). Constraints (4) to (6) calculates the total completion time and the start time of all treatments of patients for each stage at each day of the planning horizon. The treatment sequences for patients who assign to the same resource at each stage and each day are certified by Constraints (7) and (8). Moreover, the treatment sequences of patients who assign to the same staff at each stage and each day are determined by Constraints (9) and (10). The completion time of all treatments at each stage and each day is calculated by Constraint (11). The completion time of each facility and each staff at each stage and each day are calculated by Constraints (12) and (13), respectively. Constraints (14) to (16) consider the binary variables. The positive variables are certified by Constraint (17) to (20). In this study, to consider the uncertainty in the formulation, the Fuzzy programming approach is utilized. The uncertain parameters are presented as a triangular fuzzy number ($\tilde{n} = (n^p, n^m, n^o)$); where, n^p, n^m, n^o represent the pessimistic value, intermediate value, and optimistic value of the fuzzy number that is estimated by experts. In the literature review, several approaches are presented to deal with the fuzzy parameter or uncertainty factors in the constraints and objective functions (Jiménez et al., 2007). The proposed uncertain model is transformed into the equivalent auxiliary crisp mixed-integer linear model of the approach presented by Jiménez et al. (2007) due to its high efficiency. Finally, the crisp form of the Fuzzy bi-level bi-objective models as MILP model can be presented as follows. According to the above description, the auxiliary crisp scheduling model for the chemotherapy scheduling can be represented by:

$$\text{Min } z_1 = \sum_{t=1}^{T}\sum_{l=1}^{L}\left(\frac{wc^p + 2wc^m + wc^o}{4}\right)Co_t^{l,Max} \tag{21}$$

$$\text{Min } z_2 = \sum_{t=1}^{T}\sum_{l=1}^{L}\sum_{k=1}^{K_t^l}\left(\frac{wp^p + 2wp^m + wp^o}{4}\right)P_{kt}^l + \sum_{t=1}^{T}\sum_{l=1}^{L}\sum_{j=1}^{N_t^l}\left(\frac{wm^p + 2wm^m + wm^o}{4}\right)M_{jt}^l \tag{22}$$

s.t.

$$C_{ijkt}^{l} \ge S_{ijkt}^{l} + \left(\alpha\left(\frac{R_{itl}^{m} + R_{itl}^{o}}{2}\right) + (1-\alpha)\left(\frac{R_{itl}^{p} + R_{itl}^{m}}{2}\right)\right) - M\left(1 - V_{ijkt}^{l}\right) \tag{23}$$

$$\forall i \in P_t^l;\ j \in N_t^l;\ k \in K_t^l;\ t \in T;\ l \in L$$

Constraints (3), (4), and (6) to (20).

5. Solution Methodology

Some studies in the literature considered exact methods to solve their proposed models. Sarin et al. (2010) applied a Benders decomposition algorithm to solve the scheduling of the courses university problem. Li and Womer (2009) proposed a hybrid Benders decomposition to solve the resource-constrained project scheduling problem. In some researches such as Redjem et al. (2012) and Rabeh et al. (2011) the optimization software is applied to solve their problem. Whereas, some studied, namely, Gamst and Jensen (2012), Rasmussen et al. (2012), and Maenhout and Vanhoucke (2010) are considered an exact branch-and-price algorithm to solve their problems. Moreover, Trautsamwieser and Hirsch (2014) solve the scheduling of the home care problem by using the Branch-Price-and-Cut solution approach. A Lagrangian relaxation approach is utilized by Bard and Purnomo (2007) to solve their integer model. One of the contributions of this study is that the proposed model developed as the bi-level bi-objective problem. In bi-level models, there are two levels, namely the upper-level and lower-level. The upper-level and lower-level are defined as the leader and the follower, respectively. The solution space of the upper-level of the problem is determined by own constraints plus the follower problem and thus this problem is a non-convex problem. According to the proposed model, the leader's objective minimizes the total waiting time for runways and gates for all aircrafts based on their importance coefficient. Moreover, the follower's objective minimizes the total distance traveled by all passengers in the airport. In general, the proposed bi-level bi-objective model identifies the assignment of the aircrafts to the gates and runways. In addition, the scheduling of aircrafts at the airport is determined in order to use the gates and runways. There are several researches applied the exact solution methodology to solve the mixed integer bi-level linear problems (MIBLP). The literature review shows that the enumeration techniques and the reformulation techniques are two kinds of exact methods to solve MIBLP. The enumeration techniques developed based on the property of the bi-level problem that the global optimal solution lies in a corner of the feasible space determined by the upper and lower levels constraints. The enumeration techniques are applied to solve the problems in the various studies such as, Vicente et al. (1996), Chen and Florian (1992), and Tuy et al. (1993). The reformulation techniques reformulates the MIBLP by using some approaches, for example, the Karush–Kuhn–Tucker (KKT) optimality conditions. The KKT reformulate the lower-level as additional new constraints for the upper-level problem and thus the bi-level problem is converted into a single-level problem. Shi et al. (2005), Shi et al. (2006), Bialas and Karwan (1978) and Hansen et al. (1992) transformed the bi-level problem by using the KKT optimality into the single-level problem.

This paper utilized the reformulation technique that proposed by Saharidis and Ierapetritou (2009) to solve our model. According to this approach, the decomposition technique is applied to decompose the structure of the problem for facilitating solving procedure of the initial mixed integer bi-level bi-objective problem through a series sub-problems. A restricted master problem (RMP) and a slave problems (SP) and KKT-slave problem are defined as the sub-problem of the initial problem is this approach. The KKT-slave problem contains the restricted initial problem (by fixing the value of the integer variables) and KKT optimality conditions of a lower-level problem as constraints. Based on the solution of the KKT-slave problem, the active constraints of the initial problem are determined. Slave problem as another restricted sub-problem in this algorithm is formulated by fixing the feasible value of integer variables of the initial problem and considering which its constraints are active. An upper bound (UB) of the problem is determined by the slave problem when the initial problem is a minimization problem. A lower bound (LB) for the problem if the initial problem is a minimizing the problem and the value of integer variables of the initial problem are determined by the restricted master problem. The lower and upper bound of the problem are updated on each iteration of this algorithm. Moreover, in each iteration, the salve problem creates a new valid cut, for the RMP. This cut leads to the RMP converge to the optimal solution. The procedure of the proposed algorithm is started by fixing the integer variable of the initial problem. Afterwards, the KKT-slave problem is applied to transform a bi-level problem into a single-level by using KKT optimality conditions. After determining active constraints, the current slave problem determines an upper bound of the initial problem (in the case of minimization). The new cut based on the status of the slave problem is established and the optimal dual values of the current Slave problem are added to the RMP. This procedure continues until the RMP optimality condition ($(UB - LB) < \varepsilon$) is satisfied. In this algorithm, three following cuts could be established.

Optimality cuts: when the current slave problem gives a feasible solution (Saharidis & Ierapetritou, 2009);
Feasibility cuts: when the current slave problem gives an infeasible solution (Saharidis & Ierapetritou, 2009);
Exclusion Cut: when the current slave problem obtains a feasible solution, but the optimality cut does not restrict the RMP (Saharidis & Ierapetritou, 2009)

6. Computational Results

In this section, we consider a numerical example based on imperial data from an oncology center in Tehran, Iran to illustrate how the proposed model works. The computational results obtained from our proposed algorithm in this research are presented to show the feasibility and applicability of our models. The center has fixed start times and regular working hours. The 8-hour working day starts at 8:00 AM to 4:00 PM. The overtime is not considered in this center. The laboratory contains five chairs to perform the tests of patients. There are three medical rooms and oncologists in this center. Five pharmacists and 15 nurses work in the pharmacy and infusion clinic, respectively. Based on the observation of this center for two months the following test problems are established in Tables 1 and 2. The Benders decomposition algorithm for a fuzzy model is implemented in GAMS® optimization software. The test problems are solved under three α-cut (0.3, 0.5, 0.7). The objective function value (OFV) of the bi-level bi-objective scheduling model for all test problems are reported in Tables 3. Tables 4 shows the CPU time of the proposed model by solving the game based Benders decomposition. The results illustrate that by increasing the number of patients and days of the planning horizon the OFV of test problems are increased. These results represent the applicability and suitability of the proposed fuzzy model. The convergence of the proposed benders decomposition algorithm for test problem 3 ($\alpha = 0.5$) is represented in Figure 2.

Table 1: Random generation of the parameters for test problems

Parameter	Test problems				
	No. 1	No. 2	No. 3	No. 4	No. 5
P_t^l	10	20	25	40	50
T (day)	15	30	30	45	45
$\widetilde{wc}$	$U\sim(150,300)$	$U\sim(200,300)$	$U\sim(150,200)$	$U\sim(200,300)$	$U\sim(150,300)$
$\widetilde{wp}$	$U\sim(20,30)$	$U\sim(25,40)$	$U\sim(15,30)$	$U\sim(20,40)$	$U\sim(15,40)$
$\widetilde{wm}$	$U\sim(10,20)$	$U\sim(15,20)$	$U\sim(25,30)$	$U\sim(20,30)$	$U\sim(20,40)$

Table 2: Parameters for test problems

Stage	Parameter	Test problem				
		No. 1	No. 2	No. 3	No. 4	No. 5
1	$N_t^{l=1}$	2	2	5	5	5
	$K_t^{l=1}$	2	2	5	5	5
	$H_t^{l=1}$	8	8	8	8	8
2	$N_t^{l=2}$	2	2	3	3	3
	$K_t^{l=2}$	2	2	3	3	3
	$H_t^{l=2}$	8	8	8	8	8
3	$N_t^{l=3}$	2	3	4	5	5
	$K_t^{l=3}$	2	3	4	5	5
	$H_t^{l=3}$	8	8	8	8	8
4	$N_t^{l=4}$	3	5	10	15	15
	$K_t^{l=4}$	3	5	10	15	15
	$H_t^{l=4}$	8	8	8	8	8

Table 3: Objective function value of test problems for the scheduling model

Test problem	α-cut level					
	0.3		0.5		0.7	
	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2
1	81100	64800	80800	64650	80700	64430
2	165000	198430	164200	198400	163900	198350
3	188900	356410	188500	356390	188400	356360
4	223300	604830	223100	604800	222900	604770
5	269000	671340	269100	671320	268800	671250

Table 4: CPU time (min) of the proposed approach for the scheduling model

Test problem	α-cut level		
	0.3	0.5	0.7
1	30.77	30.78	30.00
2	128.28	128.58	127.79
3	301.22	301.78	301.45
4	674.34	675.88	674.10
5	912.41	913.20	913.98

Also, the First-come-First-serve policy as the current system implemented at the airport (case study) is considered to present the simulation model. MATLAB® software is utilized to simulate the real-word and then compare the simulation model with real system programming. Based on empirical data of this airport, the performance of the simulation model is evaluated and is compared with the real system. For this purpose, analysis of variance (ANOVA) is applied. F-test and T-test as the test for equality of variance ($H_0: \delta_1^2 = \delta_1^2$) and average equity ($H_0: \mu_1 = \mu_2$) for simulation model and real systems are determined. Table 5 shows the results of the ANOVA test. The results illustrate the same performance for the simulation model and real system and no significant difference between the simulation model and real systems can be seen.

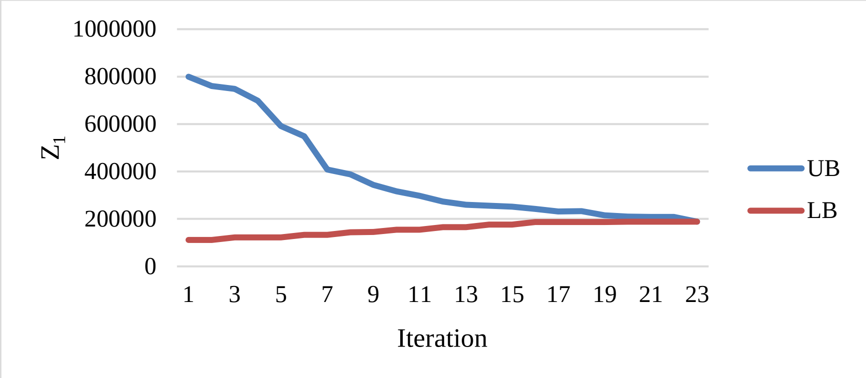

Figure 2: Convergence graph of test problem 3

Table 5: Analysis of variance results for comparison between actual system and simulation model

Factor	*F*-test (equality of variances)			*t*-test (equality of means)		
	F-value	*p*-value	$H_0: \delta_1^2 = \delta_2^2$	*T*-value	*P*-value	$H_0: \mu_1 = \mu_2$
Z_1	0.54	0.277	Not rejected at α=0.05	0.70	0.681	Not rejected at α=0.05
Z_2	0.67	0.436	Not rejected at α=0.05	1.15	0.682	Not rejected at α=0.05

In the following, the performance of the proposed bi-level bi-objective model is compared with the simulation models. For this purpose, the simulation and proposed models are implemented for 50 times, and the mean objective functions of models are compared with each other with ANOVA test. The result of the equality of mean ($H_0: \mu_1 = \mu_2$) for objective functions is reported in Table 6. The results show that, at a significance level of 0,05, there is a significant difference between the proposed model and simulation model. Thus, the result indicates the superior of the proposed model.

Table 6. Comparison between the proposed model and the simulation model

Factor	Mean		*T*-test (equality of means)		
	Proposed model	Simulation model	*T*-value	*P*-value	$H_0: \mu_1 = \mu_2$
Z_1	872	1758	1.45	0.0016	Rejected at α=0.05
Z_2	334	791	0.74	0.0021	Rejected at α=0.05

7. Conclusion

Nowadays, the chemotherapy is one of the most approaches to treat cancer who uses drugs to stop cancer cells. Increasing population and demanding for oncology services and the age-sensitive nature of cancer cause a high demand for the chemotherapy center. In this research, a bi-level bi-objective model is proposed for scheduling of the chemotherapy problem. Moreover, a fuzzy approach is applied to consider an uncertainty. The proposed model assigns the patients to the resources at each day and determines of sequence of patients. Its upper-level objective minimizes the completion time of all treatments. Meanwhile, the lower-level objective minimizes the completion time of each facility and staffs at each day. A game based Benders decomposition method is developed to solve the presented model. Empirical data are collected from the chemotherapy center in Tehran, Iran to illustrate the validation and the application of our model. The associated results of our presented model are very promising compared to the First-come-First-serve policy. Moreover, the results show that our model is more effective to improve the quality of treatment in chemotherapy centers. One of the best usages of the proposed model is that the decision makers determine the optimal staffing levels and resource allocation with this model. In real word, all patients are not accessible in the first scheduling or there are uncertainty factors like cancellations, delays in getting lab results, uncertain duration of treatment that affects the chemotherapy scheduling problem. This factors cause the patients to wait more than Scheduled time and have the side effect in their treatment process. One future research area is considering these factors in scheduling or developing uncertain or stochastic scheduling.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

The Factors Affecting Knowledge Transfer between Individuals in Organizations

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Abstract

The importance of knowledge has been increasing day by day as it is considered as one of the strategic resource for firms. Organizations try to obtain knowledge and manage knowledge effectively to gain competitive advantage in a rapidly changing environment. Knowledge management effectiveness depends on capacity of firms about creating new knowledge and transferring current knowledge, which facilitates organizational learning, offers financial advantages to firms and increases firm performance. However, it is not easy to understand how knowledge is transferred from one unit to another. The purpose of this study is to determine the factors affecting knowledge transfer between individuals in organizations. A research model which includes the variables knowledge transfer, knowledge transfer intention, tacitness, trust, information technology tools, self-efficacy, time, transactive memory system, management support, reciprocity, organizational rewards and organizational structure is constructed. In order to empirically test the model, a questionnaire was prepared based on the previous studies in the literature. A total of 377 questionnaires were collected. The gathered data were tested with regression analysis using SPSS. The results reveal that trust, self-efficacy, transactive memory system and reciprocity affect knowledge transfer intention positively. Furthermore, information technology tools, transactive memory system and trust explain knowledge transfer behavior. The study concludes with the discussion, limitations of the study and possible future studies.

Keywords

Knowledge; knowledge transfer; knowledge transfer intention

1. Introduction

Knowledge becomes a key resource that organizations own in order to compete and live in the competitive environment. The value of the organizations has been started to be measured by the knowledge they own. Today, economical power is handed by knowledge owned organizations. Natural resources, raw materials, big facilities or cheap workforce are no longer enabling competitive advantage (Barutcugil, 2002). Therefore, it is vital for the organizations to manage knowledge effectively.

Knowledge management effectiveness depends not only on creating knowledge and but also transferring knowledge to the other parties. The knowledge transfer enables employees to reach needed knowledge easily and in a fast way. Organizations and their employees should understand that knowledge value increases when it is transferred (Zaim, 2005). However, not all organizations become successful in transferring the current knowledge within the organization among employees. Understanding the factors affecting the effective transfer of knowledge may lead companies to achieve competitive advantage to their rivals.

There are studies in the literature that focus on the effects of knowledge and knowledge management on firm success. However, there is lack in studies that link daily organizational knowledge with knowledge transfer between individuals, entities or organizations (Yucelen, 2005). The aim of this study is to understand the factors affecting knowledge transfer between individuals in organizations based on a survey data collected from individuals in Turkey. A model is formed which includes the variables knowledge transfer, knowledge transfer intention, tacitness, trust, information technology (IT) tools, self-efficacy, time, transactive memory system (TMS), management support, reciprocity, organizational rewards, organizational structure. The rest of this paper is structured as follows: The second section presents an overview of the literature on knowledge transfer. In the third section, research methodology is presented; data analysis and results are given. Conclusions and suggestions for future studies are provided at the end.

2. Literature Review

2.1 Knowledge Transfer

An important part in knowledge management is to disseminate and make knowledge accessible and usable within or between organizations (Paulin & Suneson, 2012). This makes knowledge transfer as one of the most important phases in knowledge management (Duan et al., 2010). Knowledge transfer is a communication process between the source and the receiver (Cummings, 2003); exchange of knowledge between parties in an organization (Szulanski, 1996); absorbing and application of transferred knowledge by receiver (Ko et al., 2005); is a process where one unit (e.g., group, department or division) is affected by the experience of another (Argote & Ingram, 2000); transferring and dissemination of knowledge from an individual, group or organization to the other one (Gunsel, 2004).

Knowledge transfer creates new knowledge and maximizes the value of the knowledge (Kang et al., 2010). If organizations are not able to transfer knowledge internally, there will be waste of source and time in reaching current knowledge (Zaim, 2005). Knowledge transfer enables coordination and collaboration between organizational units (Pham, 2008), makes easier organizational learning (Kang & Kim, 2010), increases market share and profit of organizations (Susanty et al., 2012); increases productivity and surviving chance in the market (Baum & Ingram, 1998).

Knowledge transfer can be between the individuals, organizations, within the organization and at international level (Zaim, 2005; Duan et al., 2010). The current study focuses on knowledge transfer between individuals in an organization.

2.2 Studies on Factors Affecting Knowledge Transfer

In the literature, several factors have been studied in order to explain knowledge transfer. Knowledge specialties affect knowledge transfer speed and performance (Kang et al., 2010). Knowledge transfer depends on knowledge type and complexity; qualification and behavior of individuals who share knowledge (Boisot, 2002). Tacitness, complexity and causal ambiguity of knowledge make knowledge transfer difficult; strategic importance of knowledge easiness knowledge transfer (Eisenhardt & Santos, 2000). Organizational structure, organizational culture, reward system and knowledge technologies affect knowledge transfer (Cabrera et al., 2006; Chen & Huang, 2007; Al-Alawi et al., 2007). Individual characteristics (Baldwin & Ford, 1988), social network characteristics (McEvily & Zaheer, 1999), trust, motivation (Argote et al., 2003), social interaction (Tsai & Ghoshal, 1998), management support (Vera & Crossan, 2004), source’s expertise, structural equivalence, group identity (Kang & Kim, 2010), organizational culture (Gunsel, 2004), behavioral properties of knowledge source (Husted & Michailova, 2002), absorptive capacity of receiver (Lane & Lubatkin, 1998) and technology (Jasimuddin, 2007) affect knowledge transfer. According to the studies related with knowledge transfer, knowledge transfer decision is mostly affected by knowledge type, characteristics of source and receiver and organizational conditions. In our study, tacitness, trust, IT tools, self-efficacy, time, TMS, management support, reciprocity, organizational rewards and organizational structure are used as the possible predictors of knowledge transfer between individuals in organizations.

3. The Research Model and Hypotheses

The research model is constructed based on the studies in the literature. In the research model, factors affecting knowledge transfer and knowledge transfer intention will be explored. Intention denotes the possible action of the individual and it is considered as the previous step of the actual behavior. People first intent to do an action and then performs the behavior. Therefore, in the current study knowledge transfer intention predicts the actual knowledge transfer. The research model is shown in Figure 1.

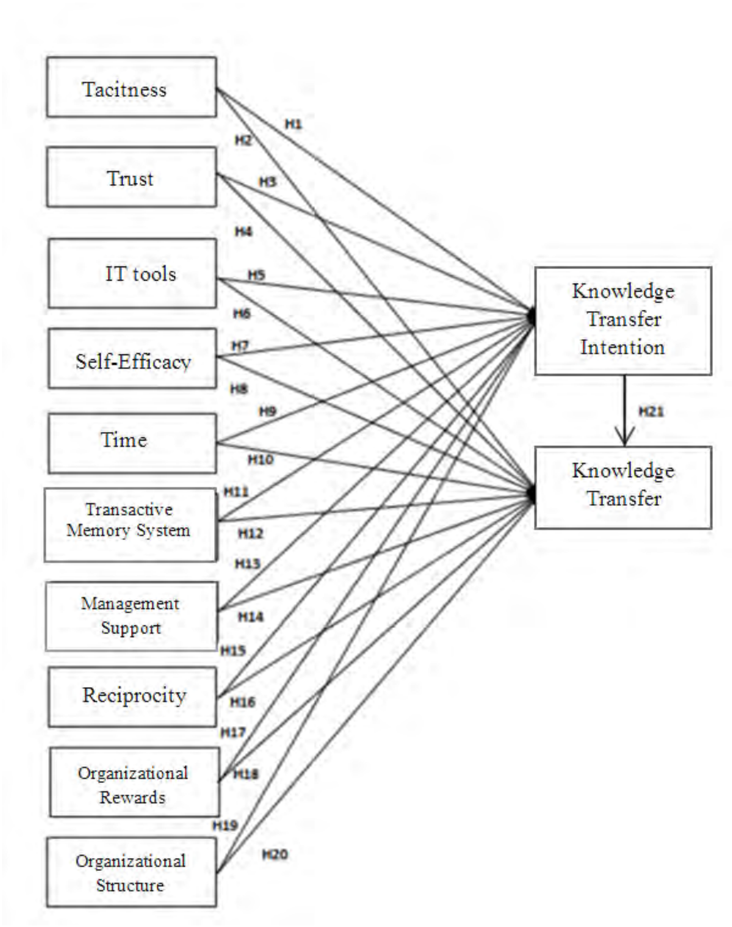

Figure 1: Knowledge Transfer Research Model

Individuals having knowledge which cannot be expressed with words and based on intuition and individual experience is called tacit knowledge (Yucelen, 2005). Polanyi (1966) explained tacitness as that we know more than we can tell. Tacitness is formed as a result of learning by doing and it is the accumulation of skills which cannot be understood directly and codified. Tacitness shows the level of difficulty in explaining and codifying knowledge (Minbaeva, 2007). Several studies explore the relation between tacitness and knowledge transfer (Yucelen, 2005; Kang et al., 2010; Jasimuddin, 2007; Gunsel, 2004). When the tacitness degree of knowledge increases, this knowledge requires more effort to be transferred by source and receiver. So source's and receiver's knowledge transfer intention decreases and knowledge transfer will be more difficult. Therefore, the following hypotheses are formed:

H1: There is a negative relation between tacitness and knowledge transfer intention.

H2: There is a negative relation between tacitness and knowledge transfer.

Trust occurred when one party trusts another party's reliability and honesty in an exchange relationship (Li, 2005). Effective knowledge transfer requires trust between individuals in all processes and the activities (Brachos et al., 2007). Trust between sides enhances knowledge transfer (Argote et al., 2003). Many studies have showed the relation between trust and knowledge transfer (Brachos et al., 2007; Li, 2005; Gunsel, 2004; Duan et al., 2010; Al-Alawi et al., 2007). Accordingly, trust between sides affects knowledge transfer. Therefore, the following hypotheses are formed:

H3: There is positive relation between trust among employees and knowledge transfer intention.

H4: There is positive relation between trust among employees and knowledge transfer.

ITs speed up knowledge transfer. With the use of IT, employees may reach any time of knowledge without time and space limitation. These technologies increase range and depth of information access and enable knowledge to be shared more rapidly, more conveniently and less expensively (Pham, 2008). IT is generally used in forming communication networks, managing knowledge and codifying knowledge. IT is mainly used in making explicit knowledge accessible and transferable. IT is also used in tacit knowledge transfer. Some firms use IT to put employees together in virtual platform instead of codifying tacit knowledge. Then employees share their tacit knowledge using IT (Susanty et al., 2012). IT tools' relation with knowledge transfer were presented in many studies (Al-Alawi et al., 2007; Choi et al., 2010; Seba et al., 2012). Therefore, the following hypotheses are formed:

H5: There is positive relation between IT Tool's benefits and knowledge transfer intention.

H6: There is positive relation between IT Tool's benefits and knowledge transfer.

Schwoerer et al. (2005, p. 115) regarded self-efficacy as "the beliefs that an individual has that he or she can successfully carry out the actions necessary to accomplish intentions". Self-efficacy is an important factor in knowledge sharing decision and influencing individuals' motivation and behavior. People who have high self-efficacy will be more likely to perform the behavior than the ones who have the low (Hsu et al., 2007). Self-efficacy motivates cooperation among group members so it enables more effective knowledge sharing and using. The relation of self-efficacy with knowledge transfer has been presented in many studies (Cabrera et al., 2006; Hsu et al., 2007). Thus, the following hypotheses are formed:

H7: There is positive relation between self-efficacy and knowledge transfer intention.

H8: There is positive relation between self-efficacy and knowledge transfer.

Nowadays time is a limited source. Internalization of knowledge is a time consuming process. Expressing the knowledge clearly or trying to transfer tacit knowledge requires time and effort. Employees can prefer to consume their time and effort on other activities instead of sharing knowledge. Employees don't have enough time to share their knowledge with the others because of the work overload they have (Husted & Michailova, 2002). Especially tacit knowledge transfer requires master-apprentice relationship, which takes much more time. According to Sandhu et al. (2011), limited time of employees for sharing knowledge, inhibit knowledge transfer. Therefore, the following hypotheses are formed:

H9: There is negative relation between limited time and knowledge transfer intention.

H10: There is negative relation between limited time and knowledge transfer.

Employees have different knowledge of specialization in a group. Who knows what should be known by group members is crucial for effective knowledge sharing in a group (Huang, 2009). TMS combines the knowledge possessed by each individual with a collective awareness of who knows what (Wegner, 1987). TMS enables cooperation between different specialized team members. Employees trust each other's knowledge and employees have necessary knowledge all together. Effective sharing and using of knowledge depends on skills of forming and managing TMS (Huang, 2009). TMS eases knowledge transfer (Borgatti & Cross, 2003), increases amount of sharing knowledge between individuals (Choi et al., 2010; Huang, 2009). Therefore, the following hypotheses are formed:

H11: There is positive relation between TMS and knowledge transfer intention.

H12: There is positive relation between TMS and knowledge transfer.

Managers have a great responsibility in order to achieve an effective knowledge transfer. First, they should be aware of the specialties of the employees and then try to construct a knowledge transfer culture in organizations (Zaim, 2005). A knowledge sharing supportive environment motivates employees to share the knowledge in organizations (Cabrera et al., 2006). The relationship between management support and knowledge transfer has been confirmed by the studies Brachos et al. (2007) and Cabrera et al. (2006). Therefore, the following hypotheses are formed:

H13: There is positive relation between management support and knowledge transfer intention.

H14: There is positive relation between management support and knowledge transfer.

Reciprocity is a form of conditional gain which means people expect future benefits from their present actions; a behavior is done in response to previous friendly actions (Hung et al., 2011). Organizational employees share their knowledge with others and expect the same when they are in need in the future (Huang et al., 2011). Reciprocity is mutual exchanging of knowledge. Several studies have showed that reciprocal knowledge exchange relationships increase employees' knowledge sharing intentions. When an employee provides valuable knowledge for the other employees, the knowledge receivers feel themselves indebted to transfer equivalent knowledge to the knowledge provider (Hau et al., 2013). Furthermore, several studies have confirmed the positive relationship between reciprocity and knowledge transfer (Hau et al., 2013; Huang et al., 2011). Therefore, the following hypotheses are formed:

H15: There is positive relation between reciprocity and knowledge transfer intention.

H16: There is positive relation between reciprocity and knowledge transfer.

Organizational rewards also provide a knowledge sharing culture in organizations. Organizations can give various forms of rewards such as salary raises, bonuses, job security, and opportunities for promotion to encourage knowledge-sharing behaviors (He & Wei, 2009). Employees may share knowledge for intrinsic motivational rewards (such as increased reputation or respect) or for extrinsic rewards (such as payment or promotion) (Seba et al., 2012). This relationship has been confirmed in the literature (Cabrera et al., 2006; Al-Alawi et al.,2007; Hau et al., 2013; Pham, 2008). Therefore, the following hypotheses are formed:

H17: There is positive relation between organizational rewards and knowledge transfer intention.

H18: There is positive relation between organizational rewards and knowledge transfer.

Organizational structure is defined as organizing, grouping and coordinating work in an organization. It is a model which shows relations within employees and within positions (Pham, 2008). Organizational structure can be a facilitator or prohibitor factor in knowledge sharing. Centralization and formalization which are the dimensions of organizational structure affect knowledge transfer. Centralization is about the decision making authority in an organization; the extent to which decision making is concentrated in a single point or diffused throughout the organization. Formalization shows that the work processes of an organization are explicitly represented and standardized under the form of written policies and rules (Pham, 2008). Knowledge transfer effectiveness increases in informal and decentralist organizations (Gunsel, 2004). According to literature there is a relation between organizational structure and knowledge transfer (Al-Alawi et al., 2007; Seba et al., 2012; Chen & Huang, 2007; Susanty et al., 2012; Pham, 2008). Therefore, the following hypotheses are formed:

H19: There is negative relation between high centralized and formalized organizational structure and knowledge transfer intention.

H20: There is negative relation between high centralized and formalized organizational structure and knowledge transfer.

Behavioral intention is measures of probability of an individual's recognize a behavior. When an individual intend to carry out a behavior, it is expected that individual tries and makes an effort more for carrying out that behavior. So realization probability of behavior increases (Gumussoy, 2009). Knowledge exchange and knowledge sharing behavior depend on intent. When intent increases, the probability of knowledge transfer occurring increases (Wang et al., 2009). Employee's knowledge sharing intent is an important indicator of knowledge sharing behavior. According to Bock & Kim (2002), there is a positive relation between knowledge sharing intent and real knowledge sharing behavior. Therefore, the following hypothesis is formed:

H21: There is a positive relation between knowledge transfer intent and knowledge transfer.

4. Methodology

A survey methodology was used in the study. In the first part of the questionnaire, demographic data was collected. In the second part, a total of 47 questions related with the variables in the research model were asked to the respondents. The questions were formed based on previous studies in the literature. Questions were taken from Pham (2008) for measuring knowledge transfer; Hau et al. (2013) for measuring knowledge transfer intention; Kang et al. (2010) and Simonin (2004) for measuring tacitness; He & Wei (2009) for measuring trust; Seba et al. (2012) for IT tools; Tseng & Kuo (2010) for measuring self efficacy; Huang (2009) for measuring TMS; Seba et al. (2012) for measuring time; Chow & Chan (2008) and He & Wei (2009) for measuring management support; He & Wei (2009) for measuring reciprocity; Pham (2008) and Al-Alawi et al. (2007) for measuring organizational rewards; Chen & Huang (2007) and Ferrell & Skinner (1988) for measuring organizational structure. Respondents indicate their agreement level to the items on a five-point Likert scale: 1 presents: strongly disagree, 5 presents: strongly agree. Survey was tested with an expert group before sending to participants.

4.1. Sample and Data Collection

Survey data was collected from 377 individuals who are working in 17 different sectors in public or private. The questionnaire was presented with an online system. Survey link was sent by emails, social networking sites, forums and mail groups. According to the demographic data, 30.2% of the participants work in public, 69.2% of them work in private sectors. 63.3% of participants are male, 36.7% of them are female. 15.1% of participants work in education, 10.3% work in banking and finance, 9.2% of them work in IT sectors. The majority of the respondents have undergraduate degree (50.9%), 41.9% of them have master degree and 6.6% of them have a

PhD degree. A 58.6% of them are engineer/expert, 19.6% of them are mid-level manager, 7.6% of them are upper level manager and 3.7% of them are technicians.

4.2. Analysis and Results

IBM SPSS 21 was used to test the model and hypotheses. According to the results, all the variables have Cronbach's alpha values greater than 0.60, which shows adequate reliability. The Cronbach's alpha values and the number of items to measure the variables are shown in Table 1.

Table 1: Reliability Analysis

Variable	Cronbach's α	Number of items
Tacitness	0.78	2
Trust	0.88	3
IT Tools	0.85	4
Self-efficacy	0.78	5
Time	0.69	3
Transactive Memory System	0.63	4
Management support	0.91	4
Reciprocity	0.75	3
Organizational rewards	0.89	4
Organizational structure	0.82	6
Knowledge transfer intention	0.86	5
Knowledge transfer	0.72	4
Total	0.93	47

Stepwise linear regression analysis was applied to search the relationships defined in the research model. First, knowledge transfer intention was chosen as a dependent variable and tacitness, trust, IT tools, self-efficacy, time, TMS, management support, reciprocity, organizational rewards and organizational structure were chosen as independent variables. According to the regression analysis result, there is a positive relation between knowledge transfer intention and reciprocity, self-efficacy, trust and TMS, as shown in Table 2 (R^2 = 0.29). Among the variables, reciprocity has the highest effect on knowledge transfer intention. Self-efficacy, trust and transactive memory system follows respectively.

Table 2: Linear Regression Analysis for Knowledge Transfer Intention

	B	Std. error	Beta	*t*	Sig.	*Adjusted R^2*
(constant)	1.656	0.217		7.632	0.000	0.30
Reciprocity	0.200	0.041	0.244	4.933	0.000	
Self-efficacy	0.215	0.044	0.225	4.941	0.000	
Trust	0.108	0.032	0.169	3.342	0.001	
TMS	0.128	0.044	0.146	2.906	0.004	
	Sum of squares	df	Mean square	F	Sig.	
Regression	36.875	4	9.219	40.024	0.000	
Residual	85.224	370	0.230			
Total	122.099	374				

In the second step, knowledge transfer was chosen as a dependent variable and tacitness, trust, IT tools, self-efficacy, time, TMS, management support, reciprocity, organizational rewards, organizational structure and knowledge transfer intention were chosen as independent variables. According to regression analysis, adjusted R^2 value is 0.11, as shown in Table 3. The results show that there is a positive relation between knowledge transfer and IT tools and TMS; a negative relation between knowledge transfer and trust. Among the variables, IT tools have the highest effect on knowledge transfer. Trust and TMS follows respectively. There is a statistically meaningful relation between trust and knowledge transfer but this relation is negative. So this relation contrasts with hypothesis 4.

Table 3: Linear Regression Analysis for Knowledge Transfer Coefficient Table

	B	Std. error	Beta	*t*	Sig.	*Adjusted R^2*
(constant)	2.333	0.282		8.270	0.000	0.12
IT tools	0.368	0.061	0.329	6.055	0.000	
Trust	-0.148	0.049	-0.175	-3.028	0.003	
TMS	0.185	0.063	0.161	2.942	0.003	
	Sum of squares	df	Mean square	F	Sig.	
Regression	25.916	3	8.639	17.323	0.000	
Residual	185.010	371	0.499			
Total	210.926	374				

5. Conclusion

The aim of the study is to understand the factors affecting knowledge transfer between individuals in organizations. A research model is developed in order to explore the effects of tacitness, trust, IT tools, self-efficacy, time, TMS, management support, reciprocity, organizational rewards, organizational structure on knowledge transfer intention and knowledge transfer. The research model was tested using data collected with the surveys. A total of 377 individuals participated in survey and then relations defined in the research model were analyzed.

According to the results, there is a positive relation between trust and knowledge transfer intention. When there is a fiduciary relationship between the individuals in an organization, knowledge transfer intention is affected positively. This finding is similar to the findings of Hau et al. (2013) who indicates that trust as a component of social capital contributes significantly to enhancing employees’ tacit and explicit knowledge sharing intentions. On the other hand, there found to be a negative relation between trust and knowledge transfer as controversy hypothesized. This result implies that when the trust between employees increases, actual knowledge transfer decreases. The reason of this result can be that in the current study knowledge transfer was measured according to knowledge transferring of employees by using IT tools. Employees who trust to each other may transfer knowledge with social interactions like face to face conservations, meetings, presentations, social activities or during lunches.

Another result revealed that, there is a positive relation between reciprocity and knowledge transfer intention. This result resembles the findings of Hau et al. (2013). In that study, they reveal that employees intend to transfer knowledge because they believe that the other employees share knowledge with themselves in return their knowledge transfer. On the other hand, there found to be no relation between reciprocity and knowledge transfer. Competition between employees in organizations can be a reason of this result or an employee who expects knowledge in return, can be willing to transfer knowledge based on social interaction.

The other result revealed that there is a positive relation between self-efficacy and knowledge transfer intention. According to this result, when an employee believes himself/herself to be skilled in sharing knowledge easily with the others or obtaining others’ knowledge by observing, increases knowledge transfer intention. Similar result exists in the literature (Cabrera et al., 2006). Results from a survey of 372 employees from a large multinational, Cabrera et al. (2006) found that that self-efficacy associated with sharing knowledge; a sense of personal competence and confidence may be a requirement for an employee to engage in knowledge exchanges.

In another finding, transactive memory system has a positive significant effect on both knowledge transfer intention and knowledge transfer. When such cooperation based medium exists between employees, employees’ knowledge transfer intent increases. Furthermore, when employees use IT tools in this medium, knowledge transfer increases between each other. Similar results exist in literature (Choi et al., 2010; Huang, 2009). A field study that involved 139 on-going teams from two major firms in South Korea, Choi et al. (2010) found that IT support in organizations has a positive impact on the development of TMS in teams, and that both TMS and IT support affect knowledge sharing positively. Using data from a sample of 290 members of 60 R&D teams in a government-supported R&D institute, Huang (2009) showed TMS positively and significantly mediates the relationship between trust and knowledge sharing.

Another result revealed that, there is no relation between knowledge transfer intention and knowledge transfer. After employees intend knowledge transfer, they can be willing to transfer knowledge based on social interactions instead of by using IT tools. Furthermore, intent may not be enough to transfer knowledge alone. Various factors can be needed for transforming intent to behavior.

Furthermore, in the current study, the effects of tacitness, organizational rewards, time, organizational structure and management support on knowledge transfer and knowledge transfer intention are insignificant. This finding is similar to the findings in the literature (Chow & Chen, 2008; Lin, 2007; Gunsel, 2004). According to Chow & Chan (2008), in the decision to share knowledge, the knowledge type whether tacit or explicit is not important. Lin (2007) obtained that there is no relation between the organizational rewards and knowledge sharing decision and intention of employees. According to Gunsel (2004), formal and centralized organizational structure doesn't affect technology transfer which is a special kind of knowledge transfer. Furthermore, the insignificant relationship between time, management support and knowledge transfer can be explained as follows: Employees can think knowledge transfer is not a time consuming process. The employees who want to transfer knowledge can transfer knowledge out of working hours. Besides, in Turkey the importance of knowledge transfer may not be understood adequately by the managers.

Although the current study contributes to the literature by exploring the factors affecting knowledge transfer and knowledge transfer intention, it has some limitations. In this study, it is only considered that knowledge is transferred through IT channels. On the other hand, with the increase in the use of social media channels may be more preferable. Furthermore, other factors such as social interactions may be included to the research model to analyze the effect. The same model can be used in order to see the differences in knowledge transfer between the organizations, partners or joint ventures.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A Review of Reverse Logistics Studies and Assessing Future Trends for Turkey

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Abstract

The studies concerning reverse logistics has gained more importance with the increase in environmental consciousness, enforcement of governmental regulations, and expectations of potential economic gains. This paper focuses on the studies in the accessible literature that are published within 2007-2016 and provides a grouping based on the country where reverse logistics principles are implemented, the sectors, and the products in concern. Also, main objectives discussed in the models and calculations for the relevant costs are summarized. Based on current outstanding sectors, future trends for reverse logistics applications in Turkey are assessed based on the potentials, benefits, and restrictions.

Keywords

Reverse logistics, supply chain management, logistics network.

1. Introduction

Nowadays, natural resources are being depleted with the increasing human population and costs are increasing in most industries. In an ordinary day, humans add 15 million tons of carbon to the atmosphere, destroy185 square miles of rainforest, create 72 square miles of tropical desert (Lu et al, 2011). Therefore, recycle or reuse of some materials are becoming more and more important. As a solution of this situation, reverse logistics has been emerged a few decades ago. Reverse logistics activities have been more attractive for most companies because of both consciousness in social and environmental issues as a result of decrease in natural resources and economic advantages they provide.

This study aims to summarize main terms for reverse logistics. A literature review is made to basically identify the trends in this important topic. Second section provides general definitions related to reverse logistics and main difficulties faced in practice. Third section summarizes the literature review under sector, product, country and problem definition and solution methodologies subsections. Section four criticizes the reverse logistics problems and solutions in Turkey. Final section concludes the study and gives ideas for future studies.

2. Reverse Logistics

There are a number of definitions for reverse logistics in the literature. However, the most accepted definition by Rogers&Tibben-Lembke (1999) states that reverse logistics is the process of planning, implementing and controlling the backward flows of raw materials, in-process inventory, packaging and finished goods from a manufacturing, distribution or use point to a point of recovery or proper disposal. According to European Group on Reverse Logistics, reverse logistics is "the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal." (www.revlogs.co.za, 19.04.2016). A reverse logistics network establishes a relationship between the market which releases used product and the new market for new products. When these markets are integrated, it is called a closed loop network (El Sayed et al, 2010).

Reasons for returning of the products can be categorized basically under five titles (Gupta, 2013) as follows:

- Customer returns,
- Repair/service returns,
- End of life returns,
- Reusable container returns,
- Leased product returns.

2.1 Driving and Enforcing Factors

There are three main incentives that drive and enforce implementing reverse logistics. These are; government policies, economic factors and environmental consciousness (Kinobe et al, 2015). Aforesaid factors have driven industrial sectors and governments to become active in reverse logistics.

Economic incentives, because the implementation of reverse logistics represent direct incomes from reduced consumption of raw materials, from adding value to recovered material and from cost reduction on waste treatment and/or disposal (Reynaldo& Jürgen, 2009). Recovery and remanufacturing can reduce the unit cost of production by 40-60% by reutilizing the product components (Keyvanshokooh et al, 2013).

Legislative incentives, because the recent legislation addressing take-back responsibilities, recycling quotas and packaging regulations, that must be accomplished by companies (Reynaldo & Jürgen, 2009). Furthermore, some products for instance electrical and electronics (cell phones, televisions, computers etc.) can no longer be landfilled due to regulations in some countries and therefore need other treatment or disposal ways, other than landfiling (Kinobe et al, 2015).

As for social incentives, as today's consumers are more and more concerned with the environmental impacts of products and services they buy, enterprises have been more and more concerned with green operations. One of the key aspects of green logistics management is reverse logistics. With consumer behavior changing as they have started to assess the environmental impacts of the products and services they buy (Edgar et al, 2013).

2.2 Difficulties in Practice

It is not possible to adopt reverse logistics principles all over the world for each sector. There are basically two main reasons: people not being aware of the applications (unconsciousness) and difficulties in implementing reverse logistics. Kinobe et al. (2015) states that because of the low processing power available, lack of market value, lack of knowledge and limited value addition activities to the products may lead to not giving enough importance to reverse logistics activities. On the other hand, it should be seen as an opportunity to build competitive advantage (Genchev, 2009). Additionally, this may be another opportunity for some firms to apply just-in-time (JIT) production system in their process because there is a strong relation between reverse logistics and JIT system (Chan et al, 2010).

Common difficulties in reverse logistics activities are additional system and facility requirements, struggling with the uncertainties and determining environmental effects. Establishing a remanufacturing system requires redesigning products to integrate design for remanufacturing standards. It also entails restructuring the firm's supply chain to integrate a new logistics chain for product collection, remanufacturing, and marketing. The majority of firms prefer to outsource end-of-life product recovery to third parties instead of setting up their own reverse supply chains (El Korchi&Millet, 2011).

The uncertainty of number of recycled products, time, cost, quality and demand is more complicated compared to forward logistics and therefore, remanufacturing reverse logistics cannot easily be controlled. General uncertainties in reverse logistics network are summarized as (Xia et al, 2011);

- Uncertain amount of waste material recycling,
- Uncertainty of recovery and arrival time,
- Uncertain of recycled products quality,
- Uncertain demand of manufactured goods,
- Uncertainty of remanufactured costs.

Another difficulty is calculating the environmental costs. The environmental costs of reverse logistics are mostly indirect cost, assisting the whole values chain rather than part of it. The environmental cost is hidden in the various costs of firms and cannot be separated from them. This means that the drivers of these environmental costs cannot be clearly identified and defined, which arose the problem of environmental costs accounting and increase the operation risks of firms. This is specially the case when no representative role can be assigned due to vague definition of environmental protection. Therefore, defining the share of environmental costs to the accountable roles in the value chain is the key to development of the low-carbon economy and the lack of this kind of mechanism will endanger the development of reverse logistics also (Lu et al, 2011).

3. Studies in the Literature Related with reverse Logistics

This study summarizes 85 of the accessible papers in the literature that had been published between 2007-2016 considering sectors/products, countries and problem types. Table 1 summarizes the sectors where reverse logistics applications have been conducted.

Table 1: Reverse logistics applications based on country

Author(s)	Country	Year	Sector/Product	Problem/Model Type	Solution Method
Ko H.J. & Evans G.W.	-	2007	General	Network Design	GA
Wang et al.	China	2007	Electric/Electronic	BLP	GA
Lieckens K. & Vandaele N.	-	2007	-	MINLP	GA
Alshamrania et al.	USA	2007	Blood	Route & Strategy	Heuristic
Sheu J.B.	-	2007	Hazardous waste	LMOAM	LINDO
Salema et al.	Spain	2007	Office document	Network design	CPLEX
Al-Anzi et al.	-	2007	-	Scheduling	Linear time Alg
Kara et al.	Australia	2007	White goods	Network design	Simulation
Gill et al.	Spain	2007	Automobile	-	-
Lu Z. & Bostel N.	-	2007	-	Location	Lagrangian heu.
Biehl et al.	USA	2007	Carpet	-	-
Chen et al.	-	2007	-	RLRFE	NDA
Mina H. & Ko H.J.	USA	2008	Cargo	MIP	GA
Kumar S. & Putnam V.	USA	2008	Automobile/electric	-	-
Efendigil et al.	-	2008	-	RLSPS	FAHP
Du F. & Evans G.W.	-	2008	Post-sale services	Network design	SS, DS, CM
Srivastava S.K.	-	2008	-	MILP	GAMS
Sheu, J.B.	Taiwan	2008	Radioactive Waste	MOO	LINGO
Wadhwa et al.	-	2008	-	MCDM	Fuzzy logic
Cruz-Riveria R. & Ertel J.	Mexico	2009	Automobile	UFLP	Sitation
Genchev S.E.	-	2009	Wholesaler	-	-
Pishvaee et al.	-	2009	General	MILP	LINGO
Kannana et al.	India	2009	Battery	MCDM	ISM, TOPSIS
Lee et al.	-	2009	-	m-rLNP	GA
Mutha A. & Pokharel S.	-	2009	-	Network design	GAMS
Nunes et al.	Brazil	2009	Construction	-	-
Lee C.K.M. & Chan T.M.	-	2009	Printer	Set coverage	GA
Lee D.H. & Dong M.	-	2009	-	Network design	Heuristic
El-Sayed M. et al.	-	2010	General	SMILP	Mosel
Achillas et al.	Greece	2010	Electric/Electronic	MILP	AMPL
Cheng Y.H. & Lee F.	Taiwan	2010	LCD	MDMM	ANP
Pishvaee et al.	-	2010	-	Network design	MOMA
Chiou et al.	Taiwan	2010	Electric/Electronic	Select alternative	FAHP
Lu et al.	China	2011	Electric/Electronic	Game theory	Shapley Value
El Korchi& Millet	France	2011	Electric/Electronic	Network Design	-
Xia et.	China	2011	General	-	-
Wilcox et al.	-	2011	Sporting goods	Liquidity analy.	Markov chain
Lambert et al.	Canada	2011	Electric/Electronic	Network Design	-
Alamri, A.A.	-	2011	General	GRLIM	General Maths
Baenas et al.	Brazil	2011	Battery	Network design	-
Zhang et al.	-	2011	Solid Waste	PIP	Linear prog.
Barker T.J & Zabinsky Z.B.	USA	2011	Medical Devices	MDMM	AHP

Author(s)	Country	Year	Sector/Product	Problem/Model Type	Solution Method
Azadi M. & Saen R.F.	-	2011	General	Select alternative	CCDEA
Senthil et al.		2012		Decision making	AHP, TOPSIS
Lee C.K.M. & Lam J.S.L.	-	2012	Medical Devices	-	-
Li R.C. & Tee T.J.C.	-	2012	Electric/Electronic	MILP	Goal Prog.
Akdoğan M.Ş. & Coşkun A.	Turkey	2012	White goods	Decision making	AHP
Divahar S.R & Sudhahar C.	-	2012	-	Select alternative	AHP
Das K. & Chowdhury A.H.	-	2012	-	MIP	LINGO
Nativi J.J. & Lee S.	-	2012	-	-	-
Govindan et al.	-	2012	Tire	Select alternative	ISM
Alamur et al.	Germany	2012	White goods	MILP	CPLEX
Xi F. & Wen-qi J.	China	2012	Automobile	Evoluation	TOPSIS
Kannan et al.	India	2012	Plastic	MILP	LINGO
Zhengiang et al.	-	2012	-	MILP	LINGO
Keyvanshokooh et al.	Iran	2013	General	MILP	CPLEX
Edgar et al.	Colombia	2013	Agro-industrial	Optimization	GAMS
Mafekheri F. & Nasiri F.	-	2013	-	SD	Simulation
Cullen et al.	UK	2013	Retailer	-	-
Lai et al.	China	2013	Manufacturing	Decision making	SUR
Nikolaouet al.	-	2013	-	Decision making	TBL
Giannetti et al.	Brazil	2013	Steel	Assessing	Emergy-based
Silva et al.	Brazil	2013	Engine	-	-
Singh S.R. & Saxena N.	-	2013	-	Optimization	General maths
Bogataj M & Grubbstromb R.	-	2013	-	Analysis	IOA, LT
Jonrinaldi & Zhang D.Z.	-	2013	-	MINLP	LINGO
Zerhouni et al.	-	2013	-	Dynamic Prog.	New Algorithm
Hu, Z.H. & Sheu J.B.	China	2013	Construction	MOLP	CPLEX
Kim J.S. & Lee D.H.	-	2013	-	Location	Heuristic
Cardoso et al.	Europe	2013	-	MILP	GAMS
Mahmoudzadeh et al.	Iran	2013	Automobile	MILP	CPLEX
Souza C.D.R&D'Agosto M.A.	Brazil	2013	Cement	MILP	TransCAD
Khora, K.S. & Udin Z.M.	Malaysia	2013	Electric/Electronic	-	-
Rodrıguez et al.	Indonesia	2013	Handmade	Assessing	Regression
Ye at al.	China	2013	General	Factor Analysis	AMOS
Bai C. & Sarkis J.	-	2013	-	Performance M.	Rough set theory
Senthil et al.	India	2014	Plastic	MDMM	AHP, TOPSIS
Jayanta et al.	India	2014	Cell Phone	Select alternative	AHP, TOPSIS
Bansia et al.	India	2014	Battery	Performance M.	Fuzzy AHP
Abdulrahman et al.	China	2014	Manufacturing	-	-
Ferri et al.	Brazil	2015	Solid Waste	MILP	C++
Kinobe et al.	Uganda	2015	Different Waste	-	-
Demirel et al.	Turkey	2016	Automobile	MILP	CPLEX
Tavana et al.	-	2016	-	Decision making	AHP, SWOT
Dixita, S. & Badgaiyan A.J.	India	2016	Cell phone	Assessing	ANOVA

Abbreviations:
UFLP : Uncapacitated facility location problem
MILP : Mixed integer linear programming
MINLP : Mixed integer non-linear programming
SMILP : Stochastic mixed integer linear programming
GRLIM : General reverse logistics inventory model
PIP : Piecewise interval programming
MDMM : Multi-criteria decision making model

CCDEA : Chance-constraint data development analysis
GA : Genetic Algorithm
BLP : Bi-level Programming
MOLP : Multi-objective linear programming
LMOAM : Linear multi-objective analytical model
RLRFE : Reverse logistics recycling flow equilibrium
RLSPS : Reverse logistics service provider selection problem
MOO : Multi-objective optimization
MCDM : Multi-criteria decision making model
TOPSIS :Technique for Order Preference by Similarity to Ideal Solution
m-rLNP : Multi-stage reverse logistics network problem
SD : System dynamics approach
TBL : Triple bottom line
MOMA : Multi-objective memetic algorithm
MP : Mathematical Programming Language
AHP : Analytical Hierarchy Process
FAHP : Fuzzy analytical Hierarchy Process
ANP : Analytical Network Process
NDA : Nested diagonalization solution algorithm
SS : Scatter search
DS : Dual simplex
CM : Constraint method
ISM : Interpretive structural modeling
TOPSIS : Technique for order preference by similarity to ideal solution
SUR : Seemingly unrelated regression
IOA : Input–OutputAnalysis
LT : Laplace transforms

3.1 Analysis Based on Sector and Product

It has been observed that reverse logistics studies have been conducted in wide range of sector. Among these sectors, electric and electronics sector stands out beside general commodities (no limitation) and different types of waste. However, a sector isn't declared in several studies that provide a framework for reverse logistics system or network. And in some of the studies, researchers don't focus on a specific product, instead they focus different type of products. In some of the studies, cases are illustrative (not real-life problem). Table 2 provides main sector/product in which reverse logistics studies have been conducted.

Table 2: Reverse logistics applications based on sector/product

Sector/Product	Number of studies	Percentage
Electric and electronics	9	15.0%
General (Different types)	8	13.3%
Automobile	6	10.0%
Battery	3	5.0%
White goods	3	5.0%
Waste	5	8.3%
Solid waste	(2)	(3.4%)
Radioactive waste	(1)	(1.6%)
Hazardous waste	(1)	(1.6%)
General waste	(1)	(1.6%)

Given the sector frequency and percentages, the sectors which is enacted with related laws (i.e. electronic, automobile, waste, battery) stands out in reverse logistics activities. This shows that legislative factor is very effective on reverse logistics applications.

In most country, batteries and electronic devices can't be released to the nature. And vast majority of waste electrical and electronic equipment quantities entering collective systems are recycled (Achillas et al, 2010). Also, about 80-85% of used batteries are recycled (Baenas et al, 2011).

3.2 Analysis Based on Country

Reverse logistics studies have been conducted in various countries. In most studies country name haven't been declared where the studies illustrate examples and/or propose a framework for reverse logistics system. Table 3 summarizes the number of studies based on the country where reverse logistics studies have been conducted.

Table 3: Reverse logistics applications based on country

Country	Number of studies	Percentage
China	8	17.4%
Brazil	6	13.0%
India	6	13.0%
USA	5	10.9%
Taiwan	3	6.5%
Iran	2	4.3%
Spain	2	4.3%

China is well-known for over using of recycling process. Therefore, it is not surprising that China is on top of the list. Brazil, India, and United States comes after China. However, since very limited number of studies are conducted in Turkey, it is not listed in the table.

3.3 Analysis Based on Problem Definition

Not all papers include a problem and a specific solution in this literature review. Some of the studies propose a framework of reverse logistics and handle different regions, cities, or sectors. Therefore, a grouping is made for the papers that consider a specific problem and a solution.

The most common problem types are listed as follows:

- Location problems,
- Uncapacitated facility location problems,
- Capacitated facility location problems,
- Optimization,
- Network design problems (Multi or single echelon, multi or single period, multi or single product)
- Assessment or evaluation (etc. performance, retailer) or choosing (etc. a 3PL provider).

Solution approaches for the aforementioned problems mainly focus on:

- Mixed integer linear programming (MILP)
- Piecewise interval programming (PIP)
- Genetic Algorithm (GA)
- Analytical hierarchy process (AHP)
- Game theory (GT)
- Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The objective functions defined for the reverse logistics problems are summarized as:

- Minimizing whole network cost,
- Minimizing fixed cost of location a facility and transportation cost,
- Maximizing total expected profit,
- Minimizing total logistics cost,
- Minimizing economic, environmental and social cost,
- Minimizing operation, collection, transportation and inventory cost,
- Choice of optimum third party logistics (3PL) firm,
- Optimum network design.

Based on the review results, it can be stated that the objective functions mainly are defined to minimize total reverse logistics costs or to maximize the profit.

4. Overview of Reverse Logistic in Turkey

There are only a number of academic studies and regional researches upon reverse logistics in Turkey. For instance a study was conducted in Thrace region with 110 firms in 2012. In this study it is proved that 47.7% of the companies are in agriculture – food – oil sector, 34.6% are in textile – shoe sector, 14% are in paper packaging, iron – steel, glass, shopping, retailing, construction, machinery, metal and various manufacturing sectors while 3.7% are in chemical – pharmaceutical sector (Gilanlı et al, 2012).

From the point of sectors, the studies are related to electrical and electronic equipment (Kılıç et al, 2015), end-of-life vehicles (Demirel et al, 2016) and electronic waste (Aras et al, 2015).

There are currently 83 laws and regulations about environment in Turkey. Most of these legislatives are related to waste and battery. Turkey has approximately 80 million population and there are over 68 million cell phones as of the date of 2013 (www.wikipedia.org, 26.04.2016). Given the enforcing factors and product potential, cell phones (they all have a battery) may be main product or sector for reverse logistics in near future.

Considering the applications in reverse logistics in other countries, a potential application sector for Turkey may focus on recycling which is an element of end-of-life products according to clustering in the first section. Firms can reduce energy use by recycling. This is an economic incentive for most sectors. It is reported that 35% of carton, paper, glass, metal, and plastic products have been recycled in Turkey (http://www.mittoplastik.com, 18.04.2016). Waste management and recycling sector has been a 5-billion-Euro market with the contribution of private sector and local government. National Recycling Course of Action which involves years 2013 through 2016 provides significant opportunities for investors (www.elektrikport.com, 18.04.2016). On the other hand, the number licensed recycling facilities (5 for batteries, 1 for aluminum, 16 for packaging, 3 for glass, 8 for electronic waste, 3 for rubber, 12 for plastics, 2 for textiles and 5 for oils: 55 in total) are still limited and beyond the required number in Turkey (www.geridonusum.org, 20.04.2016). Therefore, waste (recycling) sector can be another potential application area for reverse logistics in Turkey.

Within the scope of reverse logistics, recollection activities of used products are conducted by producers in many sectors and they are responsible for this task. However, waste management is somewhat different. Household and people's consciousness plays a key role in waste management. For this reason, municipalities, universities, and government representatives must perform nationwide programs to raise awareness of the people about environment and recycling.

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A framework to assign forklift drivers to relevant duties based on physical and cognitive factors

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Materials handling activities are the backbones of any facility for it is directly related with safely transferring the right materials at the right amount in a timely manner. Forklifts are one of the versatile equipment used in several sectors. However, the performance a forklift driver during performing an assigned duty is not related only with the forklift design but also with the environmental, physical, and cognitive factors. Therefore, this study focus on forklift drivers that operate within the facility and perform various transport duties. A framework is provided to assess the transfer duties based on the physical and cognitive workload on the forklift drivers. Several factors such as the distance of travel, fragility and value of the load are considered. Further, the effect of time pressure is assessed by use of NASA-TLX questionnaire. Statistical analysis are made for the data gathered and transport duties are grouped as hard or easy that enabled to assign experienced forklift drivers to more critical duties.

Coral Reefs Optimization Algorithm's Suitability for Dynamic Cell Formation Problem

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Abstract

Nowadays, according to mass customization, producing high variable products with small parties and competitive prices gain importance. In this context "Cellular Manufacturing System" (CMS) design is vital. Cell formation (CF) is the backbone of the CMS. Generating part families, grouping machines in cells and locating part families in cells are the stages of CF. CF problem solution approaches are informal methods, part coding analysis methods and production based methods. Clustering analysis, graph partitioning, mathematical programming and heuristic/metaheuristics can be classified in the production based methods. It is hard to find solutions subject to all constraints because of the NP-Hard structure of the problem. Heuristic/metaheuristic usage reason is this difficulty. Genetic Algorithms (GAs), Tabu Search (TS), Simulated Annealing (SA), Particle Swarm Optimization (PSO), Artificial Ant Colony (ACO), Bacterial Foraging Optimization (BFO) are some of the algorithms used to solve CF problem in recent years. It is aimed to discuss Coral Reefs Optimization (CRO) algorithm's suitability for dynamic cell formation problem. Starting point of this study is Meredith's paper using CRO in clustering problems. CRO algorithm is proposed for optimization problems by Salcedo-Sanz et al. (2013). Mobile networks and wind farm design are some of the areas that CRO implemented successfully. Coral reefs can be seen similar to machines/parts trying to find space in cells. Also Baykasoglu & Gorkemli (2015), applied agent based clustering algorithm for dynamic cell formation problem and showed the success of applying clustering algorithm's application in this area. This study's results are the other base for this research.

Keywords

Group technology, dynamic cell formation problem, Coral Reefs Optimization algorithm, meta-heuristics.

1. Introduction

Cellular manufacturing based on group technology decomposes the entire production system into several mutually separable production cells (Wu et al., 2009). Cellular manufacturing has many advantages including reduction in material handling costs, setup times, production lead time, in-process inventories, and improvement in scheduling and planning. Cell formation, cellular layout, and cell scheduling are three major steps which should be taken into consideration in a successful design of a cellular manufacturing system. One fundamental problem in cellular manufacturing is the formation of part families and machine cells. The objective of this cell formation problem is to form perfect (i.e. disjoint) groups in which parts do not have to move from one cell to the other for processing (Gonçalves and Resende, 2004).

Because of increasing variety of consumer goods and decrease in product life cycles, manufacturing organizations often face fluctuations in product demand and product mix leading to a dynamic or turbulent production environment (Rheault et al., 1995). Therefore, an optimal cell design in a period may not be optimal for remaining periods in a dynamic environment. Demand is assumed static in traditional models but in real life problems demand is changing with the variability in part demand volume and mix. To overcome the disadvantages of the traditional cellular manufacturing system, the concept of a dynamic cellular manufacturing system (DCMS) is presented. DCMS implicates to reconfiguration of manufacturing cells includes part families and machine groups at each period. There are several papers handling the CF problem according to different constraints and objectives in literature.

Efforts to establish methods aiming to solve combinatorial optimization problems have gained momentum with the improvements in computer technology. However, effective algorithms yielding optimal solutions pertinent to various combinatorial optimization problems in practice have not been developed yet Dynamic Cell Formation (DCF) problem is one of the NP-hard problems and many researchers had proposed both exact and heuristic approaches to solve the problem. Meta-heuristic methods are the most preferred methods to solve combinatorial optimization problems since they are in general obtain much better solution quality than heuristic methods do, in addition their computation time is less than that of exact methods. In this study our aim is to take a glance at the solution methods for dynamic cell formation problem briefly and then introduce Coral Reefs Optimization (CRO) algorithm which is a new bio-inspired metaheuristic.

The remainder of this paper is organized as follows. In Section 2, we review dynamic cell formation literature. CRO algorithm, the relevant literature and the research motivation are then presented in Section 3. Finally, Section 4 ends with conclusions and some future research directions.

2. Dynamic Cellular Manufacturing System and a Literature review

In order to remain competitive, a manufacturing system must have a high degree of flexibility and agility to deal with product changes. Dynamic Cellular Manufacturing System (DCMS) is one of the well-known manufacturing system that meets this requirement. Traditional cell formation problem ignores any changes in demand over time from product redesign and other factors. It assumes that product mix and part demand is constant for the entire planning horizon. In dynamic environment, a planning horizon can be divided into smaller periods where each period has different product mix and demand requirements. Consequently, the formed cells in a current period may not be optimal and efficient for the next period. So dynamic cell formation problem is reconfiguration of manufacturing cells includes part families and machine groups at each period. Reconfiguration involves swapping existing machines between cells called machine relocation; adding new machines to cells include machine replication, and removing existing machines from cells.

A schema of dynamic cellular manufacturing system includes machine relocation for two consecutive periods is shown in Figure 1 (Safaei et al., 2008). In this figure, it is assumed that the maximum cell size is equal to four. Because of the processing requirements, machine 1 must be relocated from cell 1 in period 1 to cell 2 in period 1, machine 6 from cell 3 in period 1 to cell 1 in period 2, and machine 5 from cell 3 in period 1 to cell 2 in period 2. As a result, cell 3 will become empty in period 2 and called inactive cell. Thus, the number of cells at two successive periods is different. On the other hand, machine 6 is idle in cell 2 in period 2. Therefore, because of the maximal cell size limitation for cell 2, machine 6 must be relocated from cell 2 in period 1 to another cell (say cell 3), and afterward machine 1 is replaced by machine 6 in cell 2. Actually, cell 3 in period 2 can play role of the idle machines storage.

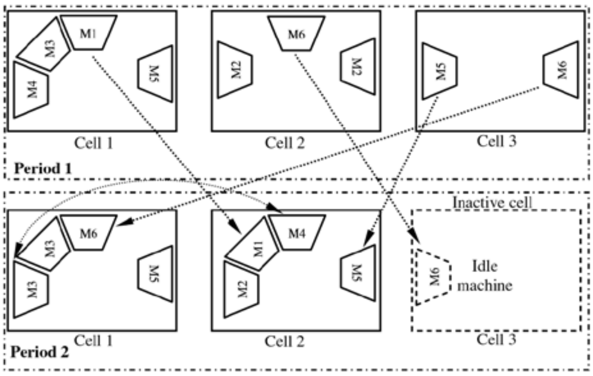

Figure. 1. A schematic view of dynamic cellular manufacturing (from Safaei et al., 2008)

DCMS was introduced by Rheault et al. (1995). In 1996, Drolet et al. investigated a four stages approach with space capacity constraint. Their objectives were machine constant cost and reconfiguration cost. Marcoux et al. (1997) showed DCMS efficiency with throughput time, machine utilization and work in process objectives. The model which is proposed by Askin et al. (1997) was consists of four stages and machine available capability. They analyzed machine variable cost and machine constant cost in their models (Safaei, 2008).

Wicks and Reasor (1999) used genetic algorithm to solve the cell formation problem under dynamic situation defined as a mixed integer program. Minimizing intercell material handling cost, reconfiguration cost and capital investment are the objectives in their model. Mungwattana (2000) analysed stochastic production requirement, routing flexibility and cell reconfiguration period by period under dynamic situation. Tavakkoli-Moghadam et al., (2005)'s model differs from the others with using different meta-heuristics; genetic algorithm, simulated annealing and tabu search for solving their problem. They also (2008) proposed an integer-linear programming model to solve DCMS problem. Balakrishnan and Cheng (2005) presented a framework consists of two stages procedure based on generalized machine assignment problem and dynamic programming.

Defersha and Chen (2006)'s view was holistic as they analyze alternative routing, lot splitting, operation sequences, machine capacity, work load balancing among cells, operation cost, subcontracting cost, tool consumption cost, set up cost, cell size limits and machine adjacency constraints together (Houshyar et al., 2014). In Jeona and Jeep (2006)'s two stages approach machine replication/duplication, machine failure, alternative process plans and operation sequences were taken in hand. Inventory cost, machine variable cost, machine constant cost and earliness/tardiness penalty were the objectives and budget and machine capacity were the constraints in their model (Safaei, 2008). Safaei et al. (2008) developed a mixed integer programming model for DCMS design. In their model a multi-period planning horizon was analyzed and product mix and part demand changes were taken in hand. They used simulated annealing (SA) meta-heuristic based on mean field annealing (MFA) to solve the model.

Cell formation and production planning problems were integrated in Safaei and Tavakkoli-Moghadam (2009)'s mathematical model to minimize inter and intra-cell movement, reconfiguration, subcontracting and inventory holding cost. In Bajestani et al., (2009)'s non-linear minimization of cell load variation and also minimization of inter-cell material handling cost, reconfiguration cost and machine purchase cost are the objectives. Kioon et al., (2009) Mahdavi et al., (2010), Saxena and Jain (2011), Rafiee et al., (2011), Ghotboddini et al., (2011), and Majazi Delfard (2013) are the other researchers in DCMS literature (Houshyar et al., 2014).

Baykasoglu &Gorkemli (2015), defined a gap in the DCMS literature. They asserted that multi-period cell formation approaches do not address dynamic problems fully. The reason is the assumption to be known beforehand for each period. It was stressed that Ben-Arieh and Sreenivasan (1999)'s study based on a distributed-, dynamic- and negotiation-based method algorithm is the first and only study in modelling dynamism, related with part demand changes in the part family formation problem. Baykasoglu &Gorkemli (2015) have proposed a novel agent-based clustering algorithm based on Ben-Arieh and Sreenivasan (1999)'s article.

Niakan et al. (2016-a) proposed a new multi-objective mathematical model in a DCF problem. They considered social criteria and uncertainty conditions. Non-dominated sorting genetic algorithm (NSGA-II) was the meta-heuristic used to solve the NP-Hard Model. Niakan et al. (2016-b) serves the DCMS as the one of the best production systems meet flexibility, agility and efficiency requierements. Niakan et al. (2016) proposed a new bi-objective mathematical programming model and a new hybrid meta-heuristic based on Non-dominated Sorting Genetic Algorithm (NSGA-II) and Multi- Objective Simulated Annealing (MOSA).

In DCMS literature the objective function was generally single. Only Aramoon Bajestani et al., Wang et al., Rafiei and Ghodsi, Shiyas and Madhusudanan Pillai 's objective functions were multi-functional (Niakan et al. 2016-b). It is seen that most of the article's data nature is certain. Only Chen and Chao and Egilmez et al. used stochastic data. Safaei et al. are the researchers used fuzzy data (Niakan, 2016-b). Defersha and Chen, Mahdavi et al., Ahkioon et al. and Aryanezhad et al. used exact methods as solving method. Genetic algorithm (GA) (Tavakkoli- Moghadam et al., Defersha and Chen, Deljoo et al. and Kia et al.), simulated annealing (SA) (Tavakkoli- Moghadam et al., Majazi Dalfard), Ant colony Optimization (ACO) (Rafiei and Ghodsi) and Tabu Search (TS) (Chen and Cao, Tavakkoli- Moghadam et al.) are the heuristics used to solve DCMS problems (Niakan, 2016-b).

3. Coral Reefs Optimization Algorithm and its Suitability for Dynamic Cell Formation Problem

Salcedo-Sanz et al. (2013-a) presented Coral Reefs Optimization (CRO) algorithm as a novel bio-inspired algorithm to tackle complex optimization problems. This algorithm artificially simulates a coral reef. Coral reefs are defined as diverse underwater ecosytems held together by calcium carbonate structures secreted by corals. Most coral reefs are built from stony corals. These stony corals are consisting of polyps that cluster in groups. Coral's fight for space in the reef is similar with solutions in optimization problems. Salcedo-Sanz et al (2013) showed this meta-heuristic's success in several continuous and discrete optimization problems. CRO was successfully implemented for the optimal service distribution problem in mobile radio access Networks (Salcedo-Sanz et al., 2012), off-shore wind farm design (Salcedo-Sanz et al, 2014-a) and daily global solar radiation prediction (Salcedo-Sanz et al, 2014-b). Salcedo-Sanz et al. (2013-b) also proposed a new algorithm based on CRO for multi objective problems as (MO-CRO). They showed the algorithm's success by comparing NSGA-II algorithm. In daily global solar radiation prediction research they integrated CRO with extreme learning machine (ELM) approach and proposed a new algorithm (CRO-ELM) (Salcedo-Sanz et al., 2014-b).

There are seven main steps in CRO algorithm. These steps are shown as below (Salcedo-Sanz et al. (2013-a), Medeiros, 2015).

1. *Starting Phase*: Generate a N x M square grid (Each square (i, j), representing different solutions to a certain problem, is able to allocate a coral (or colony of corals))

2. *Reef Initialization Phase*: Randomly assign some squares to be occupied (empty cells are left for new corals to settle and grow)

3. *Reef Formation Phase*: Starts the reef formation

3.1 Apply external sexual reproduction (broadcast spawning)

3.2 Apply internal sexual reproduction (brooding)

4. *Larvae Setting Phase*: Populate the grid

4.1 Randomly set a coral to a square

4.2 If the square is empty then the coral sets and grows

4.3 Else the coral compete to existing one by using its health function value

4.4 After a number of unsuccessful tries, the coral dies

5. *Budding/Fragmentation-Asexual Reproduction Phase:*

5.1 Sort the corals in the reef by using their level of healthiness

5.2 Duplicate a fraction of sorted corals

5.3 Try to settle in a different part by using step 4

6. *Degradation in Polly Phase:* Starts the degradation in Poly

6.1 Applies the degradation operator to a fraction of the worse health corals in the grid

7. Stops or returns to step 3.

Broadcast spawning (step 3.1) is similar to crossover and brooding (step 3.2) is similar to mutation in genetic algorithm. The initial occupation rate and health function computation of each coral are the important point in this algorithm.

Medeiros et al. (2015) are the researchers who applied the Coral Reefs Optimization (CRO) algorithm to clustering problems first time. They transformed CRO into a hybrid algorithm, like Genetic K-means Algorithm (GKA). They defined two main modifications with this aim. Coding is the first modification that means to represent of the individuals. In application coding phase is a pre-processing phase of the algorithm. Inclusion of the K-means operator in the external sexual reproduction phase (step 3.1 of algorithm) is the second modification. They also proposed three new modifications of CRO. Step 2 of the CRO algorithm was modified in CRO1. They used a criterion to rank and organize solutions into the grid, instead of random order organizing. Step 6 was the second extension of CRO. In CRO2, it is aimed to simplify the computation and to give more chance of survival for all possible solutions. They used the degradation phase less frequent and with a higher probability than the original CRO to aim these objectives. Medeiros et al. (2015) combined CRO1 and CRO2 in CRO3. They compared CRO with a hybrid genetic algorithm proposed for solving clustering problems.

Baykasoğlu&Gorkemli (2015), applied agent based clustering algorithm for dynamic cell formation problem and showed the success of applying clustering algorithm's application in this area. Baykasoğlu&Gorkemli (2015)'s, results are the base for this research. There are few articles in dynamic CF problem literature and these are multi-period approaches. Baykasoglu&Gorkemli (2015) claimed that this multi-period approach is not suitable and identified a gap. It is aimed to show CRO algorithm can be applied to dynamic cell formation problem. Machines need to be assigned in a cell, can be seen as coral's fight for space in a reef. This similarity gain more importance in dynamic cell formation problems because of the Coral reef's dynamic environment.

4. Conclusion

In order to remain competitive, a manufacturing system must have a high degree of flexibility and agility to deal with product changes. DCM system is one of the well-known manufacturing systems that meet these requirements. Gupta and Seifoddini (1990) found out that one-third of USA companies rearrange their manufacturing facilities every two years. Moreover, Marsh, Meredith, and McCutcheon (1997) concluded that layout changes could occur within six months from the last rearrangement of a cell. In this context there is a need to handle real-life problems dynamic instead of static way. As a result it is aimed to research whether CRO, a new metaheuristic, is suitable for dynamic cell formation problems.

As an evolutionary bio-inspired approach, CRO algorithm is based on the simulation of the process of coral reefs' formation and reproduction. Since it is a new method, its application is limited by areas such as mobile networks and wind farm design. To the best of our knowledge, it is not applied to DCF problem up to now. Therefore, the next step of this study is to apply CRO algorithm for DCF problem.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Event Driven Dynamic Job Shop Scheduling Under Capacity Constraints

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Abstract

There are many dynamic events like machine breakdowns, changes in due dates, job cancellations, arrival of urgent jobs etc. that makes static scheduling approaches very difficult and/or unfeasible. Under such real production environments a dynamic scheduling strategy should be adopted. In the present study an event driven job shop scheduling mechanism under machine capacity constraints is proposed. The proposed method makes use of dispatching rules and Giffler & Thompson (GT) algorithm by also taking into account job's due dates and sequence-dependent setup times. In addition to event-driven rescheduling strategy, a periodic rescheduling strategy is also devised and both strategies are compared under different scenarios. Extensive computational tests presented that the proposed approaches can improve the job shop performance in comparison to employing basic dispatching rule based approaches.

Keywords

Dynamic job shop scheduling; combinatorial optimization; heuristics

1. Introduction

Scheduling problems occur in manufacturing, logistics, transportation, construction, engineering, management areas. Scheduling problems, particularly in the production and manufacturing area is quite complex and the structure of classical optimization approaches for solving this problem is very inadequate. Therefore, researchers in disciplines such as operations research, artificial intelligence, manufacturing engineering and industrial engineering have always high-level of attention on the scheduling problem.

Scheduling problems are one of the major problems encountered in production management. The main purpose of the scheduling is the process of constructing production schedule for a given set of jobs and resources under the objective function which minimize the maximum completion time of jobs. The job shop scheduling problem is one of the most studied scheduling problems. In scheduling problems, it is quite complicated to choose the best schedule, when the number of jobs and machines increases. Because of this reason the optimal solution of the job shop scheduling (JSP) is computationally challenging and the JSP is NP-hard (Lenstra & Kan, 1979).

JSP may be described as follows: given n jobs, each composed of several operations that must be processed on m machines. Each operation uses just one of the m machines for a fixed duration. Each machine can process at most one operation at a time and once an operation initiated processing on a given machine it must complete processing on that machine without interruption. The operations of a given job have to be processed in a given order. The problem consists in finding a schedule of the operations on the machines, taking into account the precedence constraints, that minimizes the makespan. The various methods like mathematical techniques, dispatching rules, artificial neural networks, neighborhood searches, fuzzy logic, metaheuristics etc. are introduced to get an optimum (or a near optimum) solution. This definition is mostly related with the static part of the scheduling problems, real time events such as random job arrivals, machine breakdowns etc. are ignored in this definition. In many real life systems, finding the optimum solution is much more complex because dynamic events occur continuously, such problems henceforth called as dynamic job shop scheduling (DJSS) problem.

DJSS problems occur in most of the real manufacturing environments due to frequent occurrence of unexpected events. In dynamic scheduling problems, there is an infinite set of jobs that continue to arrive during the scheduling process. Moreover, all jobs are usually not available at first and there are several other disturbances like machine failure, job cancellation, due date changing etc. Such dynamic events may quickly invalidate generated schedules and makes scheduling process a dynamic on-line activity. Therefore, there is a need and extensive further research on modeling and solving dynamic scheduling problems.

The first study on dynamic job shop scheduling was published by Holloway and Nelson (1977) who proposed a scheduling system for a job shop with intermittent job arrivals. They implemented a multi-pass procedure by generating schedules periodically. Haupt (1989) surveyed the literature on heuristic priority rule-based job shop scheduling. Kim and Kim (1994) proposed a simulation based scheduling system with two major components: simulation mechanism and reactive control. The simulation mechanism evaluates various rules and selects the best one for a given job population and performance criterion. Bierwirth et al. (1995) presented a genetic algorithm based scheduling in a dynamic manufacturing environment and compared the results with the outcome of dispatching rule based simulations. Jeong and Kim (1998) developed a scheduling mechanism in which job dispatching rules vary dynamically based on information from discrete event simulation that is used for evaluating candidate dispatching rules. Sabuncuoglu and Bayiz (2000) presented the effects of several system configurations on the performance of online and offline scheduling under deterministic and stochastic environments and concluded that dispatching rules were more robust to system uncertainty and performance of online methods decrease less than offline methods in dynamic environments. Chan and Chan (2001) presented a simulation model of a flexible manufacturing system (FMS) which minimizes three performance criteria simultaneously, i.e. mean flow-time, mean tardiness and mean earliness with the dispatching rule which can be changed at a frequency that is varied by the quantity of output produced by the system. Baykasoğlu et al. (2002) presented a multiple dispatching rule based meta-heuristic solution approach for job shop scheduling problems (JSSP). Choi and You (2006) presented an extensive performance analysis of dispatching rules for a framework of simulation-based dynamic scheduling in one-of-a-kind production (OKP). Singh et al. (2007) presented a simulation model using changing dispatching rules to improve performance criteria in a dynamic system. Vinod and Sridharan (2008) also proposed some dispatching rules for dynamic job shop scheduling by considering sequence dependent set-up times, their proposed rules performed better than the previous simple rules. Zhang et al. (2009) described an approach into the evaluation and optimization of dispatching rules by integrating the simulation and response surface methodology (RSM). Baykasoğlu and Özbakır (2010) analyzed the effects of dispatching rules on the scheduling performance of job-shops with different flexibility levels. They defined four different flexibility levels for operations. Five dispatching rules are evaluated according to mean tardiness as the performance criteria for the scheduling system. After detailed analysis it is found that the effect of dispatching rule selection on job shop performance weakens as the job shop flexibility increases. Kaban et al. (2012) experimented the impact of the single dispatching rules and hybrid dispatching rules by using simulation technology. Chen and Matis (2013) developed weight biased modified rule (WBMR) for job shop scheduling problem and numerical experiments of the WBMR rule demonstrated the superior performance of this scheduling heuristic to minimize the tardiness of jobs in comparison to other dispatching rules. Sharma and Jain (2014) presented the performance of nine dispatching rules with consideration of sequence-dependent setup times for discrete event simulation model of a stochastic dynamic job shop system.

This research makes use of Giffler and Thompson (1960) (G&T) algorithm with dispatching rules under machine capacity and sequence dependent setup times constraints along with dynamic events (new order arrivals, machine breakdowns, and order cancellations, due date changes). We consider event-driven rescheduling strategy. For evaluating the relative performance of the scheduling, mean tardiness is chosen. The results of the proposed G&T algorithm are compared with dispatching rules. In this study for the first time dynamic job shop scheduling problem with new order arrivals, machine breakdowns, rush orders, order cancellation, change of the due dates under machine capacity and sequence dependent setup times is tackled.

2. Problem description and proposed solution methodology

2.1. Problem description

Production orders enter the job shop environment depending on stochastic inter arrival time. The distribution of the job arrival process follows closely the Poisson distribution (Rangsaritratsamee et al., 2004). Therefore, the time between arrivals of jobs is exponentially distributed. Type of an arriving job is stochastic and selected from a discrete uniform distribution.

The setup times for the machines are significant. In standard DJSS problem, setup times are included in the processing times or neglected to simplify the problem. But, this is not a realistic application and setup time is considered separable. The interval between the end of processing of the current job and the beginning of processing of the next job is named setup time. We consider sequence-dependent setup times. Setup time for one job depends on the job previously processed and a separate setup time matrix is defined for each machine.

In the standard manufacturing system, the machines are continuously available and machine capacity is unlimited. But in the real manufacturing system, the machines are not continuously available because of cleaning, machine breakdown or preventive maintenance and meanwhile each machine capacity is limited and each machine is ready for processing only in certain time intervals. The unavailability periods are considered, corresponding to some preventive maintenance data, are known in advance, fixed at the end of each shift and this data can easily be included in preparing production schedule process. Machine breakdowns may occur on the machines. The mean time between failure (MTBF) and the mean time to repair (MTTR) are two parameters to express the unreliability of the machine. MTBF and MTTR times for the machines are assumed to be following an exponential distribution.

In the real manufacturing system, the changes of orders are adapted to the scheduling process instantly. Although the customers declare the due dates, some customers may postpone due date to a later date or get an earlier date. Some customers may request the late delivery of order, and then these orders will be postponed. When the customer wants to receive the order as soon as earlier, the order is called rush order and the schedule is reconstructed with this additional rush order constraint. During rescheduling process, priority is assigned to rush order and the operations of the rush order are assigned to the required machines primarily. On the other hand, some customers have cancelled their production orders. After the order cancellation dynamic events, the remaining operations of this order are deleted from the task list. Moreover, we suppose that the operations are strictly non-preemptable, which means that once started, the execution of an operation can be interrupted neither by a maintenance task nor by another operation.

Rescheduling is the process of updating an existing production schedule in response to unpredictable real-time events to minimize its impact on the system performance. It needs to address two issues: how and when to react to real-time events. The proposed algorithm is presented to answer these questions. In this proposed methodology, event-driven rescheduling strategy is used. In the event-driven rescheduling strategy, the schedule updates whenever an unexpected events happened. Under the periodic strategy, schedules are generated at regular intervals, which gather all available information from the shop floor. The schedule is constructed and not revised until the next scheduling period begins, dynamic events are accumulated until the next rescheduling period. We analyze both the periodic and event-driven rescheduling scheduling strategies in our experiments.

2.2. Proposed solution methodology

In this study, we employ G&T's algorithm to generate initial population of good and diverse individuals with the dispatching rules. G&T algorithm may produce the easiest diverse schedules in JSSP. We briefly describe the proposed G&T algorithm as follows:

Notation

i	job
j	operation
k	machine
O(i, j, k)	the j'th operation of job i that needs to be processed on machine k
S_t	the partial schedule that contains scheduled operations at t'th iteration
Ω_t	the set of schedulable operations at t'th iteration
F_t	the finished time of the set of schedulable operations at t'th iteration
s(i,j,k)	the earliest time at which operation (i, j, k) ϵ Ω could be started
p(i,j,k)	the processing time of operation (i, j, k)
f(i,j,k)	the earliest time at which operation (i, j, k) ϵ Ω could be finished, $f(i,j,k) = s(i,j,k) + p(i,j,k)$

Proposed G&T algorithm:

Step 1: *Initialize $S_t = ø$; Ω is initialized to contain all operations without predecessors.*

Step 2: *Determine $f^* = min_{(i,j)\,\epsilon\,\Omega}\{f(i,j)\}$ and the machine m^* on which f^* could be realized.*

Step 3: *(1) Identify the operation set $(i^1, j^1)\ \epsilon\ \Omega_t$ such that (i^1, j^1) requires machine m^*, and $s_{(i1,j1)} < f^*$.*
(2) Choose (i, j) from the operation set identified in (1) accordance with dispatching rule. If more than one operation that enables the dispatching rules will be chosen at random.
(3) Add (i, j) to S_t.
(4) Assign $s_{(i,j)}$ as the starting time of (i, j).

Step 4: *If a complete schedule has been generated, stop. Else, delete (i, j) from Ω_t and include its immediate successor in $\Omega_{(t+1)}$ then go to Step 2.*

According to Giffler and Thompson algorithm, the earliest starting time and earliest completion time of an operation has a high priority. But, the proposed approach gives a high priority to an operation according to the dispatching rules. Until all operations are processed, the algorithm constructs an active schedule repeatedly. We give an example for illustrating the proposed G&T algorithm. Table 1 shows the initial information of the example. As shown in this table, this example has three products with eight operations. The processing time for the capable machines of each operation and the machine numbers for each product are shown in Table 1. The problem is solved by G&T algorithm with SPT dispatching rule and the iterations of the solution are expressed in Table 2. As shown in Table 2, makespan of 25 hours is obtained for this problem and Figure 1 shows the Gannt chart of this problem.

Table 1: Data of Example

Product	Machine no/Processing Time(hour)		
	Operation 1	Operation 2	Operation 3
Product 1	M5 (5)	M1(2)	M4(4)
Product 2	M2(4)	M4(8)	M1(4)
Product 3	M5(2)	M3(4)	-

Table 2: The Solution Series

Iteration 1	Ω_1={O(1,1,5), O(2,1,2), O(3,1,5)} F_1={5, 4, **2**}, S_1={O(3,1,5)}
Iteration 2	Ω_2={O(1,1,5), O(2,1,2), O(3,2,3)} F_2={7, 4, **6**}, S_2={O(3,1,5), O(3,2,3)}
Iteration 3	Ω_3={O(1,1,5), O(2,1,2), -} F_3={7, **4, -**}, S_3={O(3,1,5), O(3,2,3), O(2,1,2)}
Iteration 4	Ω_4={O(1,1,5), O(2,2,4), -} F_4={**7**,12, -}, S_4={O(3,1,5), O(3,2,3), O(2,1,2), O(1,1,5)}
Iteration 5	Ω_5={O(1,2,2), O(2,2,4), -} F_5={**9**,12, -}, S_5={O(3,1,5), O(3,2,3), O(2,1,2), O(1,1,5), O(1,2,2)}
Iteration 6	Ω_6={O(1,3,4), O(2,2,4), -} F_6={**13**,12, -}, S_6={O(3,1,5), O(3,2,3), O(2,1,2), O(1,1,5), O(1,2,2), O(1,3,4)}
Iteration 7	Ω_7={-, O(2,2,4), -} F_7={-, **21**, -}, S_7={O(3,1,5), O(3,2,3), O(2,1,2), O(1,1,5), O(1,2,2), O(1,3,4), O(2,2,4)}
Iteration 8	Ω_8={-, O(2,3,1), -} F_8={-,**25**,-},S_8={O(3,1,5), O(3,2,3), O(2,1,2), O(1,1,5), O(1,2,2), O(1,3,4), O(2,2,4), O(2,3,1)}

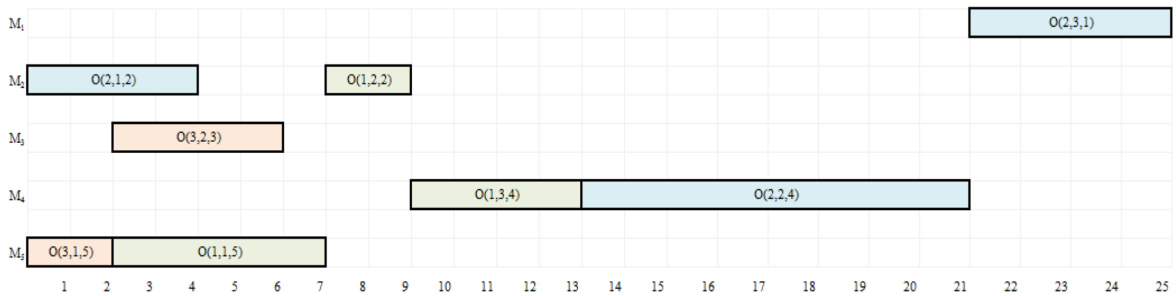

Figure 1: Gannt Chart of job shop scheduling

3. Experimental Study

We needed to consider the generation of test instance because there are no test problem in the related literature. Ten different job types are processed at the job shop and the distribution of the order arrival process follows an exponential distribution with a mean of fifty time-units. The number of operation per job type is assigned randomly between two and fifteen. A purely random sequence is utilized to represent the more difficult control problem. Each job has unique operation route and the job routings are fixed. Each operation of jobs processes unique machine and has unique processing times. The number of operations needed for processing follows a uniform distribution with a minimum of fifty and maximum of one hundred time units. Sequence dependent setup times vary uniformly in the range of eight -fifteen time units. Mean time to machine repair (MTTR) and mean time between failure (MTBF) are uniformly distributed with an exponential distribution and two distributions are used respectively:expo(60), expo(1140). In real life manufacturing systems, each shift is processed 480-time units generally and experiments are conducted with each shift 480-time units. Three scheduling periods, 120, 240, 360-time units are preferred. Each machine has different available time in each shift, 400, 420, 450, 440, 450, 460-time units. In our experiments, the due date of the fifth order is changed 900-time units at 200-time units. The fourth order is cancelled at 350-time units. The design specifications of the proposed case is summarized in Table 3. A part of the solution for EDD dispatching rule under event-driven rescheduling strategy is given in Figure 2 to visualize the real life case clearly. All the experimets were coded by MATLAB programming language and tested on a PC with Intel Core i5 2.40 GHz CPU and 16 GB of RAM.

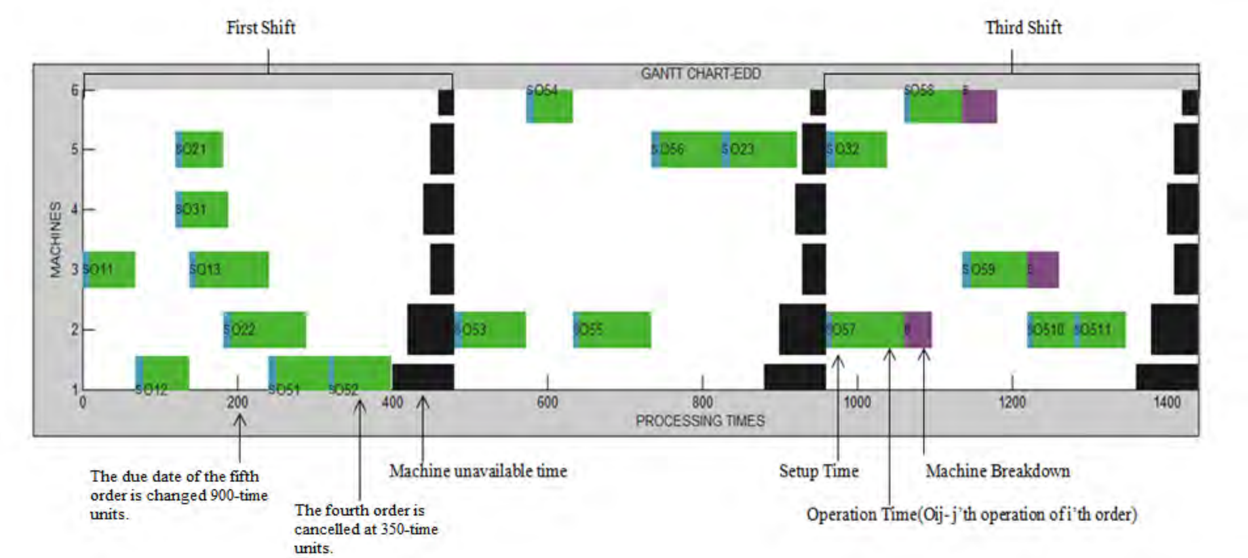

Figure 2: Visualization of the proposed case

Table 3: Design specifications of the presented case

Characteristic	Specification
Number of machines	6
Number of job types	10
Processing time	U[50,100]
Setup time (sequence dependent setup time)	U[8,15]
Setup time (setup time consecutive operations of jobs)	8
Setup time (the first assigned job to the machine after the breakdown or shift)	10
Machine breakdown MTBF	Exponential (1140)
MTTR	Exponential (60)
Scheduling periods	120, 240, 360
Machine capacities	M1-400, M2-420, M3-450, M4-440, M5-450, M6-460

In this study, to test the performance of the proposed algorithm, dispatching rules are used as benchmarks. A dispatching rule is used to select the next job with highest priority to be processed from a set of jobs awaiting service at a machine that becomes free. In the present work, the following dispatching rules are used to make job sequencing decision: FIFO, SPT, EDD, LPT, LWKR, MWKR, FOPNR, GOPNR, SL, CR, ALLOPN, SOPN, SWKR, SALL. Figure 3 shows the results of the dispatching rules for dynamic job shop scheduling problem with periodic and even-driven rescheduling strategies and the best result of the dispatching rules is obtained from the event-driven rescheduling strategy. Figure 4 depicts the results of the G&T algorithm with dispatching rules for DJSS problem with periodic and even-driven rescheduling strategies. Dispatching rule based G&T algorithm with event-driven rescheduling strategy obtains the best results. The comparison of the proposed algorithm with the dispatching rules is given in Figure 5. The results of dispatching rules based G&T algorithm with event-driven rescheduling strategy yielded better results in all comparisons.

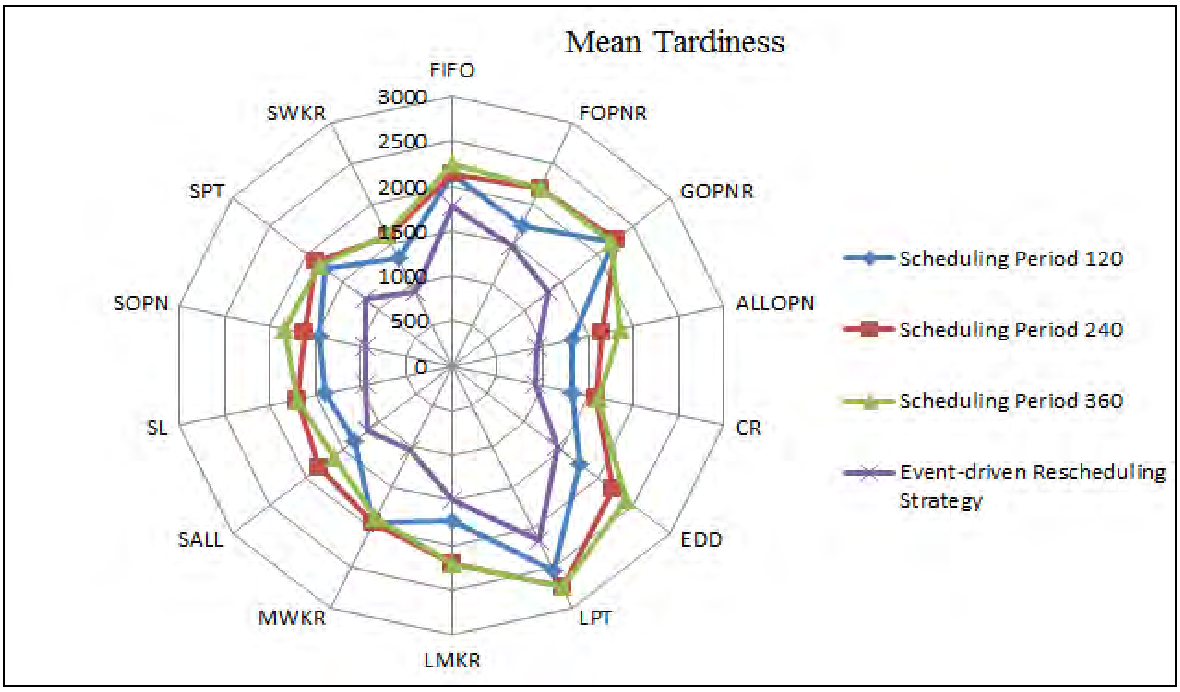

Figure 3: The results of the dispatching rules for DJSS problem

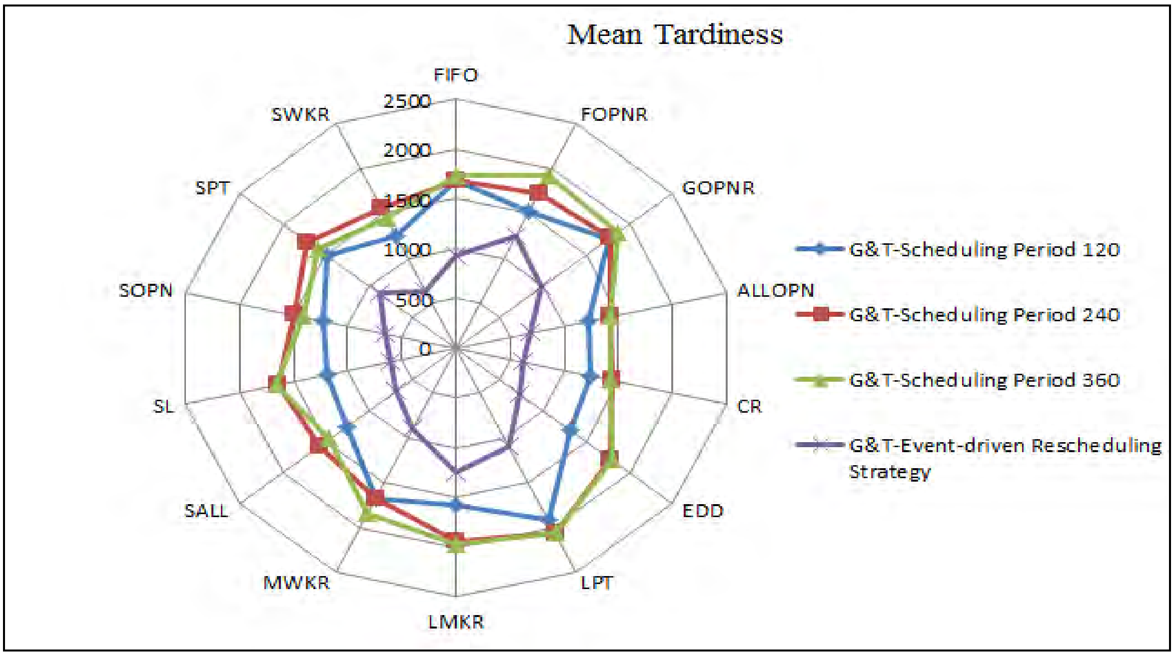

Figure 4: The results of the G&T algorithm with dispatching rules for DJSS problem

5. Conclusions

In this study, dispatching rule based G&T algorithm is proposed for dynamic job shop scheduling problem with release dates, due dates, sequence-dependent setup times and machine capacity constraint. Dynamic events such as changes in due date, job cancellation, order arrivals, arrivals of urgent job and machine breakdowns trigger the rescheduling process. Numerical experiments are conducted. The results of the proposed algorithm under event-driven rescheduling strategy show that the proposed algorithm is able to find competitive solutions.

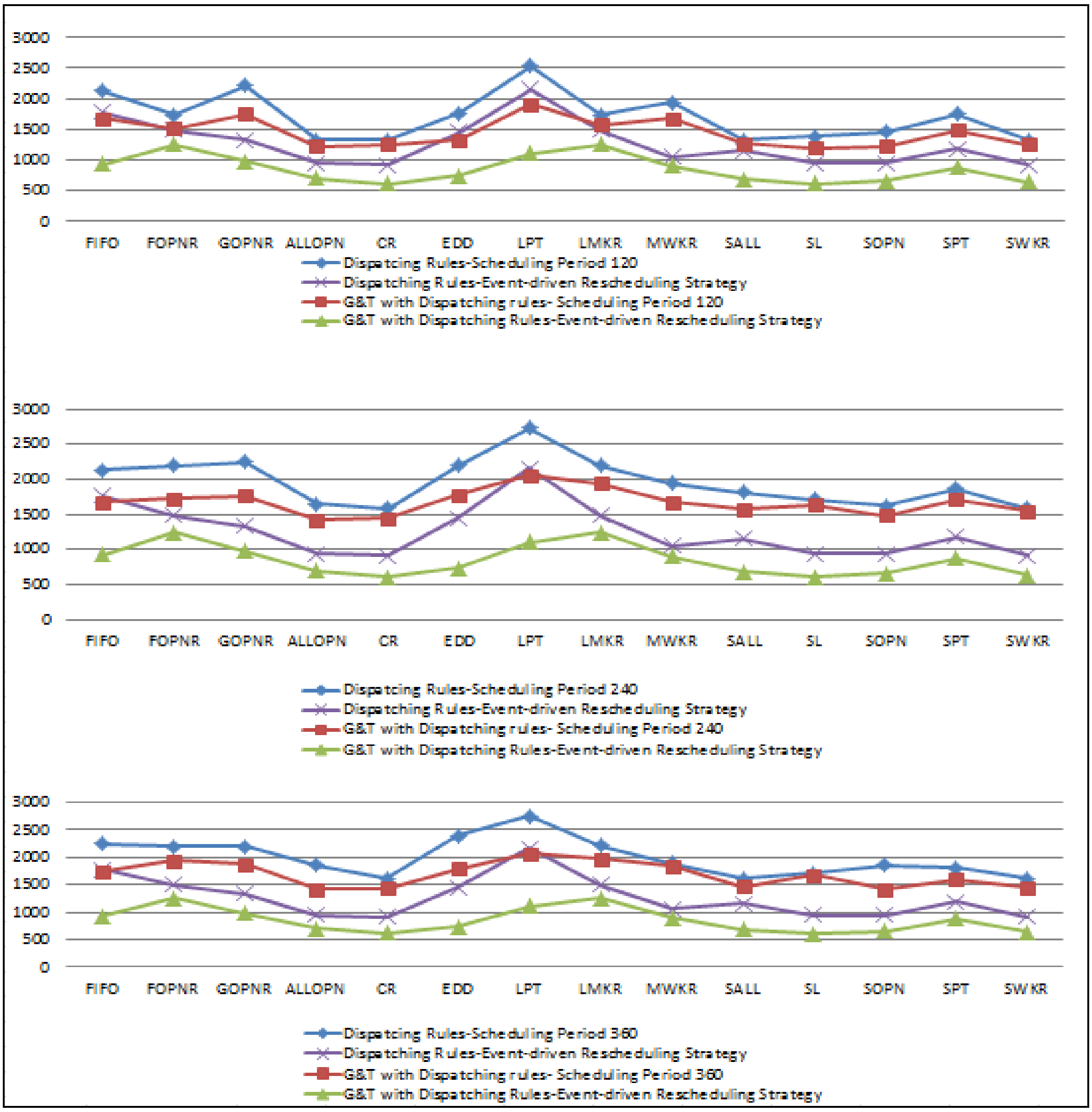

Figure 5: Comparison of the dispatching rules and proposed algorithm under rescheduling strategies

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Biography

Adil Baykasoğlu received his B.Sc., M.Sc. and PhD degrees in Mechanical Engineering and Industrial Engineering areas from Gaziantep and Nottingham. He is presently a full Professor and chair at the Industrial Engineering Department of Dokuz Eylül University. He has published around 500 academic papers with more than 4000 citations, 3 books and edited several conference books on operational research, computational intelligence, quality, supply chain management, and manufacturing systems design. He acts as editor, associate editor and referee for many scientific journals and serving on the board of several academic journals. He is also an active member of many academic and professional institutions like “International Society of Agile Manufacturing”, “Turkish Chamber of Mechanical Engineers”, “Turkish Fuzzy Systems Association”, “Turkish Operational Research Association” etc. He is awarded by TUBA, TUBITAK, METU and several other institutions for his scientific contributions.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Modeling and Simulation of Transport of Insulin Aerosol into the Lungs at the Level of Trachea

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In this work, we investigate the transport of aerosols in the upper airways of the human lung. We adopt here a kinetic point of view: the aerosol is governed by a partial differential equation on a probability density which different variables describe particles. This approach is derived from the kinetic theory of gases of Maxwell and Boltzmann [1]. Given the complexity of the geometry of the alveoli, our study was limited to the trachea (Figure 1), which is considered as a cylindrical pipe flattened back, expanded from larynx to the carina; its physiological role is: conduction, humidification and heating the air inhaled with the particle capture. The numerical modeling of flow and transport of particles becomes an indispensable complementary tool allowing the numerical prediction of the behavior of the aerosol in the respiratory tract. The mathematical modeling of transport in the tracheobronchial tree has already been the subject of several studies, including theses [2, 3]. We found in the previous two books a detailed description of the modeling of the pulmonary tree, its geometry and physiology as well as the ventilatory mechanics. This area of research is very active.

Naturally, the complex geometry and the mobile of the lung, the different flow regimes of the air, the nature of the aerosol, the aerosol/fluid interaction are criteria to be considered when establishing the model. This study focuses on the simulation of pulmonary transport in the trachea of insulin aerosol, the Vlasov equation [4] is an equation describing the behavior of the aerosol into the trachea. To solve this equation, we used the finite difference method with the implicit scheme. The simulation results show the variation of the density of the particles as a function of the time and the position. From these results, it was found that the time of the Transport is very short, so the displacement of this drug is very fast at the trachea. This simulation gives us a general idea of how the particles are transported along the trachea.

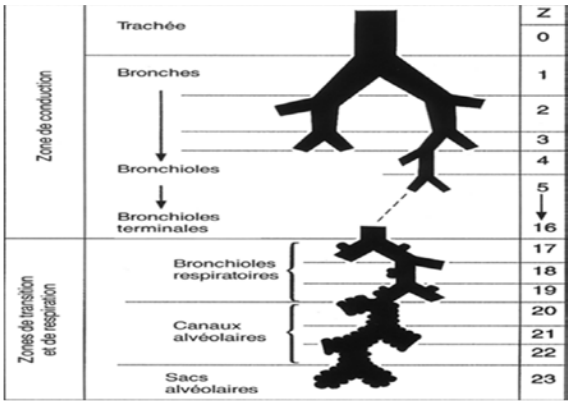

Figure 1. Description of bronchial and alveolar tracheobronchial regions by model Weibel [1]. Grippi diagram taken from [2].

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Vehicle Routing Problem in Omni-Channel Retail Distribution

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Abstract

This paper considers the vehicle routing problem arising in omni-channel retail distribution systems. A retailing business is called omni-channel retail business when customers can either order products online or get them by physically visiting the retail stores. In such systems, products ordered online are usually satisfied from the products available at the retail stores. Therefore, two distribution systems arise in omni-channel retailing. The first distribution system delivers products from a central warehouse to retail stores while the second distribution system delivers products from retail stores to the end consumers. In this paper, we present a mathematical model to describe this problem and propose two solution methods; a nearest-neighbor heuristic and an ant-colony algorithm. We also generated new benchmark problem instances to evaluate and compare the performance of the proposed solution methods.

Keywords

Vehicle Routing Problem, Supply Chain Management, Omni-Channel Retailing, Distribution Systems.

1. Introduction

We consider the vehicle routing problem (VRP) arising in the distribution system in omni-channels. In omni-channels, customers can choose to get the products by physically visiting the store, or to order products online to be delivered at their home. This problem is motivated from the distribution system found in most of the chain stores businesses (such as: Best Buy, Shoppers Drug Mart, Sears, etc.). In the supply chain of these stores, products are distributed to the retailers from a central warehouse through the retailer distribution system using a fleet of vehicles. Products ordered online are delivered to the consumers from the inventory available at the retailers. Usually, the products ordered online are shipped through regular mail or by a separate fleet of vehicles. Shipping through mail increases the product cost where this extra cost is paid either by consumer or by the company. On the other hand, using a separate fleet of vehicles for satisfying online demand increases the distribution cost. In this paper, we integrate the existing retailer distribution system with the consumer distribution system by utilizing the same fleet of vehicles. Utilizing the same fleet of vehicles not only reduces the transportation cost, but also it reduces the CO_2 emissions which have been a global concern in recent years.

In distribution system of the retailers, the fleet of vehicles located in the depot is used to satisfy the orders of the retailers. These orders are satisfied by the products available at the central warehouse. The distribution system of online consumers utilizes the same fleet of vehicles to satisfy online orders. Those online orders are satisfied from the products available at the retailers. In this paper, we integrate two distribution systems by using the same fleet of vehicles to deliver products to retailers as well as consumers. Thus, the VRP arising from this integrated distribution systems can be considered as a generalization of two VRP structures. The first VRP structure is the Capacitated Vehicle Routing Problem (CVRP). The second VRP structure is the Pickup and Delivery Problem (PDP).

The literature related to this problem is divided into two directions: research considering CVRP and research considering PDP. In CVRP, a fleet of identical vehicles (initially settled in the depot) serves a number of customers. Each vehicle visits a group of customers only once such that the total demand of the customers does not exceed the capacity of the vehicle. One the other hand, in PDP, which is a generalization of VRP, transportation requests between customers are the only distinguishing feature. In PDP, each transportation request is assigned to a source and a destination node, i.e., each customer requires a quantity to be delivered from a specific location. It is required to find the best route that satisfies all the transportation requests without violating the vehicles capacity. Another form of the problem is the dial-a-ride problem where the transportation of customers is considered instead of the transportation of goods.

The VRP was first introduced as a generalization of the travelling salesman problem (Dantzig & Ramser, 1959). This work is considered as a basis from which several variants evolved and many researches were directed. Many different solution approaches were proposed to solve the problem. A review of the most recent exact algorithms focused on the CVRP can be found in Baldacci et al., 2010. Many heuristics were used to find near optimal solutions. An attribute based hill climber heuristic, which is considered as a variant of the general tabu-search heuristic, was proposed by Derigs & Kaiser, 2007. A memetic algorithm was suggested to solve the problem (Nagata & Bräysy, 2009). A particle swarm optimization was applied in Ai & Kachitvichyanukul, 2009. An artificial bee colony algorithm was proposed in Szeto et al., 2011. In Reed et al., 2014; Abdulkader et al., 2015, an ant colony algorithm was considered for the waste collection problem. For recent research in VRP and its variants refer to (Laporte, 2009; Eksioglu et al., 2009; Lahyani et al., 2015).

The PDP is considered one of the most popular forms of the VRP due to its wide range of applications. It has been extensively studied in the literature. The precedence relations of the PDP were introduced to the basic travelling salesman problem by Lokin, 1978. The first general model and survey for the problem were introduced by Savelsbergh & Sol., 1995. Kalantari et al., 1985 presented a branch and bound algorithm for the single and multiple vehicle PDP. A mixed integer linear programming formulation for the multiple vehicles PDP was presented by Lu, & Dessouky, 2004. They developed a branch and cut algorithm to solve the problem. A number of survey papers is published recently dealing with the PDP (Berbeglia et al., 2007; Parragh et al., 2008 a; b).

In this paper, we use an ant colony (AC) algorithm to solve the proposed problem. The AC algorithm was first introduced to solve combinatorial problems (Dorigo et al., 1996). It was applied to solve the travelling salesman problem. The algorithm was inspired by the behavior of real ants. The ants communicate by leaving material (pheromone) on every route they travel. The higher pheromone will guide the succeeding ants to the most preferred route. The first application of the AC for solving the VRP showed good results but did not improve the best known solutions (Bullnheimer et al., 1999). The AC was used to solve the dynamic VRP and produced good results (Montemanni et al., 2005). An improved AC was introduced to solve the VRP with backhauls (Gajpal & Abad, 2009 a) and to solve the VRP with simultaneous delivery and pickup (Gajpal & Abad, 2009 b). A multiple AC system was proposed for the VRP with time windows and uncertain travel times (Toklu et al., 2014). The AC was hybridized with local search procedures to solve the multi-compartment VRP (Abdulkader et al., 2015). It is clear that the AC algorithms have been used efficiently to solve variants of the VRP.

2. Problem description and formulation

In this section, we present a brief description of the problem and provide its mathematical formulation.

The proposed problem considers two sets of customers served by a fleet of homogenous vehicles. The first set consists of r retailers and includes the customers who require some products to be delivered from distribution center. The second set consists of c consumers and includes the consumers who have ordered products online. We assume that a decision on the retailers that will satisfy the demand of consumers has been already made. In other words, the retailers used for satisfying the demand of consumers are known in advance. We consider that the demand of consumers is negligible compared to the demand of the retailers. Thus, any amount of consumers demand can be carried out by the vehicles without violating the vehicle capacity. The fleet of vehicles is available at the depot. The proposed model is formulated to determine the least cost routes of vehicles in such a way that:

- Every route starts and ends at the depot.
- Every retailer is visited by only one vehicle and only once.
- For every retailer, a set of consumers who require service from this retailer is predetermined in advance.
- The total load of the vehicle arising from the delivery demand of the retailers does not exceed the vehicle capacity.
- Every consumer is visited by only one vehicle and only once.

- Every consumer is assigned to only one retailer.
- If a retailer will be fulfilling the demand of a certain consumer, both of the consumer and that retailer must be visited by the same vehicle.
- If a retailer will be fulfilling the demand of a certain consumer, this retailer must be visited before the consumer.

The problem can be defined using graph theory as follows:

Let $G = (V, A)$ be an undirected graph with a set of vertices $V= \{0, 1,\ldots, (r+c)\}$ where r is the number of the retailers and c is the number of the consumers. Node $\{0\}$ is the distribution center from where products are delivered to retailers. Here, $R= \{1, \ldots, r\}$ are the retailers, and $C= \{r+1,\ldots, r+c\}$ are the consumers. Nodes $N= \{1, 2, \ldots, r, r+1, \ldots, r+c\}$ are the customer nodes (retailers and consumers) served by a number of K identical vehicles (initially located in the depot). Each retailer $i \in R$ has a quantity d_j to be delivered. Each retailer $i \in R$ serves a set of consumers $S_i$where each consumer is assigned to only one retailer. Let C_{ij} be the distance (cost) for travelling from node i to node j. Let T_{ij} be the time for travelling from node i to node j.

Let the decision variable Q_i^k be the vehicle load after service node i. Let the decision variable B_i^k be the service start time of node i by vehicle k. Let X_{ij}^k be binary flow variables equal to 1 if the arc $(i\ j)$ is traversed by vehicle k, and 0 otherwise.

Mathematical model

The proposed model can be formulated as follows:

Minimize

$$Z = \sum_{k\in K}\sum_{i\in V}\sum_{j\in V} C_{ij}^k X_{ij}^k \tag{1}$$

Subject to:

$$\sum_{k\in K}\sum_{j\in V} X_{ij}^k = 1 \qquad \forall i \in N \tag{2}$$

$$\sum_{k\in K}\sum_{i\in V} X_{ij}^k = 1 \qquad \forall j \in N \tag{3}$$

$$\sum_{l\in N} X_{il}^k = \sum_{l\in N} X_{lj}^k \qquad \forall i \in R, j \in S_i, k \in K \tag{4}$$

$$\sum_{i\in N} X_{0i}^k = \sum_{j\in N} X_{j0}^k \qquad \forall k \in K \tag{5}$$

$$Q \geq Q_j^k \geq \left(Q_i^k - d_j\right)X_{ij}^k \qquad \forall i \in V/C, j \in V/C, k \in K \tag{6}$$

$$B_j^k \geq (B_i^k + T_{ij}) \qquad \forall i \in R, j \in S_i, k \in K \tag{7}$$

$$X_{ij}^k \in \{0,1\} \qquad \forall i \in V, j \in V, i \neq j, k \in K \tag{8}$$

The objective function (1) represents the total travelling cost of all arcs traversed by all vehicles. Constraint (2) ensures that exactly one arc enters a customer node. Constraint (3) ensures that exactly one arc leaves a customer node. Constraints (2) and (3) ensure that each node is visited exactly once by only one vehicle. Constraint (4) along with constraints (1) and (2) ensure that, if a consumer is served from a certain retailer, both of the retailer and the consumer are visited by the same vehicle. Each vehicle starts its route from the depot and terminates it at depot {0} according to equation (5). Consistency of the vehicle capacity is conserved by constraint (6). Constraint (7) ensures that if retailer i is serving consumer j, then this retailer is visited before the consumer.

3. Solution methods

The proposed problem falls under the category of NP-hard problems. Therefore, VRP literature considers heuristics and metaheuristics to solve the problem. In this paper, we propose two solution methods to solve the problem. These methods are described in the next two subsections.

3.1 Nearest-neighbor heuristic

We propose a nearest-neighbor (NN) heuristic to solve the problem. In this heuristic, the vehicle starts its route from the depot loaded with its full capacity and visits a randomly selected retailer. Due to the fact that consumers are served from retailers, the first customer visited in each trip must be a retailer. After visiting a retailer the load carried by the vehicle is reduced by the quantity required of this retailer. The vehicle then proceeds to the customer with the minimum travel distance (from the current customer) among feasible customers (i.e., retailers or consumers). A retailer is considered feasible if its required quantity does not exceed the available quantity in the current vehicle. On the other hand, a consumer is considered feasible if it should be served from one of the retailers that were visited by the current vehicle. The vehicle proceeds from one customer to another till there are no feasible customers are available to visit. This means that the available quantity in the vehicle is not sufficient to satisfy the demand of any of the unvisited retailers. In addition, all consumers who require service from the retailers visited by the current vehicle have been visited already. When there are no more feasible customers to visit, the vehicle returns back to the depot. Another trip starts from the depot to serve remaining customers.

3.2 Ant-colony algorithm

We also propose an ant-colony (AC) algorithm to solve the problem. The AC is an algorithm used for finding near optimum solutions for NP-hard problems. It is based on the behavior of the real ants in selecting the best route from their nest to the source of food. The algorithm is used in VRPs to construct routes by considering the vehicles as ants moving from one customer to another. Customers are chosen according to a probability function composed of two parts: the distance from current customer to the next customer and the pheromone value. Pheromone is an indication on the history of an arc, i.e., how frequently this arc was chosen in previous solutions. After visiting a customer, the ant modifies the available quantity in the vehicle. In addition, it keeps history of visited customers. The algorithm can be described in the following steps:

1. Deposit initial pheromone values

The pheromone value τ_{ij} indicates how frequently arc *(ij)* was used in previous solutions. In the beginning of the algorithm, the initial pheromone values are set to the same value for all arcs. The initial pheromone value is equal to the inverse of the total travelled distance calculated from an initial solution. We used the solution found by the NN heuristic to calculate the initial pheromone value.

2. Route construction

We used *m* ants to construct complete tours. Each ant starts from the depot and chooses first customer randomly which must be a retailer. The Then, the next customer is chosen from the list of feasible customers. The list of feasible customers should contain: retailers who can be visited without violating the vehicle capacity and consumers who should be served from retailers visited by the current vehicle. In order to choose the next customer, a random variable q is calculated between $[0,1]$. If $q > q_0$ the next customer will be chosen based on a probability function calculated by equation (9). Otherwise, the next customer is the feasible customer with maximum attraction value ε_{ij} which is calculated by equation (10).

$$P_{ij} = \begin{cases} \dfrac{\varepsilon_{ij}}{\sum_{l \in N_i} \varepsilon_{il}} & if\ j \in N_i \\ 0 & otherwise \end{cases} \tag{9}$$

where N_i is the list of feasible customers that can be visited and ε_{ij} is the attraction value.

$$\varepsilon_{ij} = (\tau_{ij})^{\alpha} (\mu_{ij})^{\beta} \tag{10}$$

where μ_{ij} is the inverse of the arc distance.

3. Pheromone update

After constructing all routes, the distance is calculated for all routes. The best solution, i.e., the route with minimum travelled distance, is used to update the pheromone values using equation (11). Pheromone is reduced on all arcs and increased on arcs visited by the best route.

$$\tau_{ij}^{new} = \begin{cases} \rho \times \tau_{ij}^{old} + 1/L^{best} & if\ arc\ ij \in best\ route \\ \rho \times \tau_{ij}^{old} & otherwise \end{cases} \tag{11}$$

where L^{best} is the total length of the best solution in each iteration.

4. End the algorithm and report the best solution

The ant colony described above uses number of parameters. We set these parameters on the basis of the parameter used in the literature. The number of the built routes depends mainly on the number of iterations and the number of used ants. When both of them increase, the number of explored routes increases. Thus, increasing the number of iterations and the number of ants increases the solution quality. However, it also increases the computational time. We used 100 iterations to keep the solution time of the AC algorithm comparable against the NN heuristic. We used (α=1 and β=2) and set (q_o=0.9). We used (ρ=0.9) to update the pheromone with new and existing experiences of ants.

4. Numerical experiments

In next subsections, we present the data generation, and show the results for the proposed solution methods.

4.1 Data generation

There are no benchmark problems for VRP in omni-channels because it is not considered in the literature. This problem is formulated for the first time in this paper. In this work, we created 20 problem instances in order to evaluate the performance of both the NN heuristic and the AC algorithm. We used a number of retailers equals to 10, 15, 20, and 25 and number of consumers equals to 25, 50, 75, 100, and 150. The *X* and *Y* coordinates of retailers and consumers are created randomly between [0,100]. The demand of the retailers is generated between 25 and 50 unit while the capacity of the vehicles is 100 unit. The list of served consumers for each retailer is generated randomly.

4.2 Computational results

The proposed NN heuristic and AC algorithm were both coded in C programming language and the 20 problem instances were solved. The AC algorithm was run for 100 iterations. The average computational time for the NN heuristic is 0.1 seconds while the average computational time for the AC algorithm is 0.25 seconds. The problems were solved using a server that operates four 2.1GHz processors with 16-core each and a total of 256 GB of RAM. The results are presented in Table 1. Column 2 and 3 show the number of retailers and the number of consumers used in each problem instance respectively. Column 4 and 5 present the total length calculated using the NN heuristic and the AC algorithm respectively. The improvement in total length of the AC algorithm over the NN heuristic is presented in column 6. The percentage improvement is calculated using equation (12).

$$Improvement\ (\%) = \frac{NN - AC}{NN} * 100 \tag{12}$$

Table 1: The results of the 20 problem instances using the NN heuristic and the AC algorithm

Problem	No. of retailers	No. of consumers	Total Distance NN	Total Distance AC	Improvement (%)
1	10	25	1617.98	1300.57	19.62
2	10	50	1777.25	1630.22	8.27
3	10	75	2579.25	2315.6	10.22
4	10	100	2563.06	2159.49	15.75
5	10	150	3084.45	2883.56	6.51
6	15	25	1858.8	1669.51	10.18
7	15	50	2180.38	2038.08	6.53
8	15	75	3325.65	2721.87	18.16
9	15	100	3456.99	3121.18	9.71
10	15	150	4205.3	3972.17	5.54
11	20	25	2509.56	2131.83	15.05
12	20	50	2838.03	2400.28	15.42
13	20	75	3545.21	3037.73	14.31
14	20	100	3592.32	3390.5	5.62
15	20	150	4541.59	4131.86	9.02
16	25	25	2188.02	1745.98	20.20
17	25	50	2966.88	2518.31	15.12
18	25	75	3689.08	3200	13.26
19	25	100	4099.65	3420.9	16.56
20	25	150	4338.16	4041.05	6.85
Average			3047.88	2691.535	11.69

From Table 1, it can be noticed that the average total length calculated using the NN heuristic is 3047.88 unit distance. The average total length calculated using the AC algorithm is 2691.535. It is obvious that the results obtained from the AC algorithm are better than the results obtained using the NN heuristic in all problem instances. The average improvement in the total length of the AC algorithm compared to the NN heuristic is

11.69%. The minimum improvement is 5.5%. This improvement shows the effectiveness of the proposed AC algorithm.

5. Conclusion

In this paper, we introduced the vehicle routing problem arising in the omni-channel retailing. In this problem, the existing retailer distribution system is integrated with the consumer distribution system by utilizing the same fleet of vehicles. We presented a mathematical model for the problem. We proposed two solution methods; a nearest neighbor heuristic and an ant colony algorithm. We generated 20 problem instances to test the proposed methods. The results showed that, on average, the ant colony algorithm produces 11.7 % better results than the nearest neighbor heuristic.

In this paper, a group of consumers is assigned to each retailer. These assignments are usually determined in advance before the solution of the routing problem. The assignments are made according to the product availability at each retailer. A suggested research direction is to include the decision of assigning consumers to retailers, in the routing problem. This can be done by generating demand for each consumer and creating inventory of the required products at each retailer. In this case, the retailers shipping the consumers orders are decided by the product availability. This decision can be made simultaneously with selecting the best routes.

Acknowledgement

The authors acknowledge the funding received from University of Manitoba and the NSERC discovery grants to support this research.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Collision and Conflict-Free Airport Ground-Traffic Management

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Abstract

This paper introduces a mathematical model for realizing a collision and conflict free airport ground-traffic management. While the safety of aircrafts including other moving vehicles such as towing vehicles, catering and cargo carriers etc. is treated as the highest priority, the proposed mathematical model addresses the business objectives of both airline companies and the airport authorities. In literature, collision free aircraft trajectory planning has been studied independently from gate and runway utilization problems. In practice, the performance of taxiing operations (collision free aircraft-trajectory planning), directly impacts on the performances of gate and runway operations. Any bottleneck during taxiing operations due to collision avoidance leads to unrealistic gate and runway scheduling if problems are studied independently. In this paper, we discuss a mathematical model that studies the gate and runway scheduling problem simultaneously with the collision-free airport ground-traffic-control problem.

Keywords

Airport operations, Conflict-free taxiing, Simulation, Design of experiment

1. Introduction

Airline industry has been growing continuously during recent years while airport capacities have been stagnating. Despite the negative impact of September 11 attacks and ongoing global financial unknowns, demand for airline services has been steadily increasing. In most of the major markets including Europe, North America and large part of Asia, since early 90s, both total seat capacity and number of airline companies have increased significantly. Growth in industry further triggered a fierce competition among airline companies as well as independent airport authorities. Emerging market conditions have brought many challenges along with its benefits. Overcrowding airport terminals, congested airspaces around the airports particularly in North America and even congestion in airspaces between airports in Europe, and frequent delays are some of the challenges for the airline industry as well as for the transportation authorities to tackle. Furthermore, volatility in fuel prices, increasing labor costs and unpredictable weather conditions in most parts of the world are forcing many airline companies to face extreme financial challenges.

Congestion on the airport surface is a major constraint for the available capacity of the air transportation system. Economically, congestion reduces the turnaround efficiency; whereas environmentally, slower traffic on the airport surface or in the airspace around airports causes substantial air-pollution and noise emissions which negatively impact the local population. Furthermore, congestion causes concerns for air traffic controllers' workloads and increased risk of taxiway and runway conflicts. The practical and financial difficulties of increasing capacity through airport expansion enforces all involved parties to investigate enhanced airport ground movement efficiency by the intelligent use of the existing resources mainly being the runways, taxiways, and gates.

While the runways are only used for take-offs and landing, taxiways are a set of paths or area connecting the gates and runway and other facilities in the airport. Usually the path of taxiway for a departure aircraft leaving from each gate is pre-defined and if there exists a conflict among aircrafts traveling on the same taxiway, one of them will stop and wait until the conflict is resolved. When an airport has a small quantity of runways and a simple taxiway structure, runway capacity is the main reason of flight delay. In Europe, for example, it is estimated that aircraft spend 10-30% of their flight time taxiing, and that a medium range aircraft expends as much as 5-10% of its fuel on the ground (Deonandan and Balakrishnan (2010)). Therefore the efficiency of taxiway planning becomes the main restricting factor of taking full advantage of airport capacity.

The efficiency of airport utilization depends largely on the taxiway schedules of moving vehicles on the ground. This is because a small aircraft will suffer instability from the wake-vortex generated by a large aircraft preceding it. In contrast, a large aircraft will suffer relative low turbulence from air flow caused by a small aircraft before it. Therefore, re-arranging the landing/takeoff sequence by switching the order of different type of aircraft, delay may be minimized or alleviated in many situations. Currently, controllers in airport control towers are responsible for the overall management of surface traffic at the airport which strictly depends on the qualifications of personnel. Managing all ground activities, even under normal operating conditions, is a challenging task and it requires at least three different controllers (one for each of the ‘pre-flight’, ‘taxiways’ and ‘runways’ areas) to manage airport traffic flow. Each controller focuses on an optimal plan for his/her own area and tries to deliver the aircraft to the next controller in an efficient way. Moreover, basis of the ground traffic control is the principle of priority and the focus is always “safety first”. It is assumed that the aircraft landed or the one in the final phase of the approach takes precedence over the airplane departing. As the density and complexity of airport operations increases, safety concerns related to operations on the surface are mounting, especially under the condition of low visibility. Indeed, in the current ground traffic control system, aircraft cannot be sufficiently monitored and guided under low visibility conditions and, as a consequence, the theoretically available capacity of an airport cannot effectively be utilized.

The literature on ground traffic management or airport operations management consists of three categories: Gate management (Yu 2015 and Narciso 2015); Runway management (Bennell 2013); and Taxiing operations (Tjahjono , 2014, Jiang 2015). Most studies in the literature consider gate, taxiway, and runway scheduling decisions separately (Dorndorf et al., 2008, and Nikulin and Drexl, 2010 for gate scheduling; Atkin et. al., 2014, Lee and Balakrishnan, 2012, and Roling and Visser, 2008 for taxiway scheduling; Malik et. al., 2010 and Montoya et. al., 2011 for runway scheduling). The models develop in those fields generally focus on the optimization of resource usages: gate, taxiway, and runway utilizations. Operations Research literature frequently emphasize that optimization of a subsystems will not guarantee a global optimization. Optimal taxiway scheduling or optimized runway sequencing will not lead to an efficient airport traffic management solution if the problems are solved independently (Yu, 2015).

Runway capacity is a major bottleneck in airport operations. Poor scheduling of gates also leads to unnecessary congestion. Despite the performance of taxing operations directly impacts on both runway utilization and gate operations, it has not received an adequate attention from academic community. Taxiing operations are coordinated by ground traffic controllers from airport towers. The process is strictly dependent on the qualifications of personnel. In order to increase the capacity of ground operations, a number of virtual reality based displays and simulation tools have been developed. Although advanced visualization solutions have helped ground traffic controller significantly particularly under poor visibility conditions, no airport has achieved a fully automated taxing operations. This paper is motivated from the taxiway and runway scheduling problems and presents a mathematical formulation that integrates taxiway schedules with runway sequencing.

2. Problem Statement

This paper introduces a mathematical model for realizing a collision and conflict free airport ground-traffic management. While the safety of dynamic-objects including aircrafts, towing vehicles, catering and cargo carriers etc. is treated as the highest priority, the proposed mathematical model addresses the business objectives of both airline companies and the airport authorities. The goal is to navigate all moving vehicles through edges while respecting both taxiway and runway safety rules. In this paper, we modeled airport operations in a unified way from runways to gates. However, the special focus has been given on collision free navigation throughout an airport.

Growing demand on air transportation, aging infrastructures and increasingly unpredictable weather conditions are continually creating challenges for airport management authorities. While the safety is the foremost important consideration, economic consequences and human emotions require adequate attention as well. Although a more detailed list is possible, in order to better define the objectives of this paper we emphasize on following objectives. In general the objectives of the airport management are:

- Ensuring a collision free navigation for all moving objects includes aircrafts, catering, fueling and luggage handling equipment and other authorized vehicles;
- Minimizing arrival and departure delays;
- Minimizing environmental footprint;
- Improving the working conditions of Air Traffic Controllers (ATCOs)
- Generating a business model that is sustainable and profitable

In order to achieve the aforementioned goals fully or partially, a holistic airport management strategy is required. The term holistic in our case refer to coordination between airspace around airports, available capacity on runways; collision free taxiing operations and finally the gate operations. Tackling with an objective to optimize any of these sub-problems independently will not lead to an acceptable solution for the entire problem. The current literature mainly focuses on the sub-problems due to the computational complexity of, in general, the scheduling and sequencing problems which is the integral part of the airport operations.

2.1 Gate Operations

In general gate operations consider the assignment of an aircraft to a gate and consequently to determine the arrival and departure times of that aircraft in such way that all aircrafts are served with minimum arrival and departure delays. In reality on the other hand, gate operations deals with a number of additional operations such as pushback tractors, minor maintenance of aircrafts, fueling, cleaning and catering and luggage handling. All these additional operations are subject to limited resources which are shared among a large number of competing aircrafts (the term *competing* refers to individual aircrafts, may or may not belong to the same airline company, require service from these resources). Therefore, the realized performance of gate operations will always be subject to the performance of competing services that are required to be performed at gates. Furthermore the traffic conditions within the airport and in the airspace around the airport fill further impact the realization of predetermined schedules. Therefore, studying gate scheduling independently will only lead to a superficial planning may only be used as a tactical planning tool. At the operational level, a number of frequent updates are required.

2.2 Taxiing operations

Airport taxiing operations deal with the routing and timing of aircrafts on paths between runways and gates (Yu and Lau, 2014). At the operational level, conflicts among moving vehicles and resulting traffic conditions require further attention. From the perspective of mathematical programming, taxing operations are modeled as a network problem with taxiing ways (arcs) connected to intersections (nodes). The objective is to determine a unique path that transports an airplane from gates to runways (or from runways to gates). Most literature assumes that there are only a subset of paths is possible for an aircraft to reach the destination. Hence the problem becomes the selection of a path from predefined sets. Problem becomes more challenging if the timing variables, that determines the arrival and departure times to/from a node, are incorporated. Furthermore, a number of recent works highlighted the importance of fuel consumption during taxing (Ravizza et al, 2013). Most major airports such as Chicago O'Hare, New York JFK or Montreal Dorval are either within close proximity or inside of residential limits of these cities. Therefore, continually increasing air traffic has been a major source of air pollution for the residents. Delays within airports due to taxiing operations and runway capacity limitations are causing aircrafts to burn fuel for non-value-added activities (waiting). As a result, a new line of research work focusing on taxiing operations from fuel consumption perspective has risen. One proposed solution is the use of automated guided electric driven towing tractors to handle surface traffic in airports (Zhang and Wang, 2014). Another line of work that concerns of taxiing operations is the conflict resolution in airport surface operations. Studies on collision avoidance focus mainly on technological advances where conflicts are identified during taxing through sensors or visual cues (virtual or augmented reality) and corrected through delaying or re-routing aircraft (Williamson and Spencer, 1989 and Cahill et al, 2012). The common problem of these works is the separation of business performance objectives from safety. In practice, safety is ensured through a number of conflict constraints that cause significant delays. Therefore, a taxing planning independent from collision avoidance or collision avoidance independent from taxing planning will lead to unrealistic solutions for practical usage.

2.3 Runway scheduling

The objective of the runway scheduling is to determine an optimal sequence of aircraft landings and departures on single or multiple runways. One of the important constraints is the minimum separation distance between aircrafts. While large airplanes can follow any other aircrafts with a minimum timespan, it requires longer timespans if a smaller aircraft is following a large one (Solveling and Clarke, 2014). The problem can be studied as the traditional lot size scheduling problem which is known to be an NP-Hard problem. However, runway traffic is directly linked to the taxiing operations and air-traffic management. Therefore, an optimal condition for the unique runway scheduling problem may not lead to a good airport management solution.

3. Modeling

In the proposed airport configuration, taxiway is modeled as a directed graph where aircraft travels on edges to reach either the node defines the end of a runway or the node defines the destination gate. Let us consider an airport configuration includes N nodes (gates, runway entrance and exit locations, and intersections along the taxiways) connected by L edges. The goal is to navigate all moving vehicles through edges while respecting the airport safety rules.

3.1 Objective function

In the objective function, we minimize the arrival and departure delays. However, the objective function can easily be expanded to serve to the needs of various airport authorities. Topics such as minimization of fuel consumption, minimization of maximum delay, maximization of support vehicle utilization or minimization of cost due to any or all such concerns.

$$\min \sum_{f \in F} (Da^f + Dd^f) \tag{1}$$

Where Da^f and Dd^f are the arrival and departure delays respectively.

3.2 Model constraints

Let us now define the decision variable used in the model. $x_l^f = 1$ indicates that link l is in the path of flight f. Ta_l^f and Td_l^f are timing constraints that determines the arrival time of flight f at link l and the departure time of flight f from link l respectively. Consequently following set of constraints ensures a path for each airplane from the gates to runway (or opposite direction) and arrival and departure times to the links on the path.

$$\sum_{l \in L(v \in \{Gate, Runway\}^f)} x_l^f = 1, \forall f \in F \tag{2}$$

$$\sum_{l \in \vec{L}(v)} x_l^f = \sum_{l' \in \overleftarrow{L}(v)} x_{l'}^f \leq 1, \forall f \in F, v \in N \tag{3}$$

$$Ta_l^f, Td_l^f \leq x_l^f, \forall l \in L, f \in F \tag{4}$$

$$Td_l^f - Ta_l^f \geq Tmin_l, \forall l \in L, f \in F \tag{5}$$

$$\sum_{l \in \vec{L}(v)} Ta_l^f \geq \sum_{l' \in \overleftarrow{L}(v)} Td_{l'}^f, \forall f \in F, v \in N \tag{6}$$

$$\sum_{l \in L(v \in \{Gate, Runway\}^f)} a_l^f \geq T_{ARRIVAL}{}^f \; \forall f \in F \tag{7}$$

$$\sum_{l \in L(v \in \{Gate, Runway\}^f)} d_l^f \geq T_{DEPARTURE}{}^f \; \forall f \in F \tag{8}$$

$$Da^f \geq T_{ARRIVAL}{}^f - \sum_{l \in L(v \in \{Gate, Runway\}^f)} a_l^f \tag{9}$$

$$Dd^f \geq T_{DEPARTURE}{}^f - \sum_{l \in L(v \in \{Gate, Runway\}^f)} d_l^f \tag{10}$$

Next set of constraints are for the conflict resolution. The goal is to make sure no two airplanes use the same link from opposite directions at the same time. In order to ensure such conflict condition not to occur, the proposed mathematical model delays the arrival time of an aircraft to a link from opposite direction if the link is already occupied by another aircraft. In order to achieve this goal, we introduce a binary variable $z_l^{ff'} = \{0, 1\}$. Consequently, the following two constraints are introduced.

$$Ta_l^{f'} > Td_l^{f} - M\left(1 - z_l^{ff'}\right) \tag{11}$$

$$Td_l^{f} > Ta_l^{f'} - Mz_l^{ff'} \tag{12}$$

The MILP formulation ensures a safety between aircrafts traveling at the same link from opposite directions

Finally, constraints 13 and 14 are included in the model to ensure a separation distance between departing aircraft against the wake vortex impact. The decision variable $y_l^{ff'} = 1$ implies that flight f departs before f'. Therefore, arrival time of flight f' to the runway should be at least the required separation time between flight f and flight f'. In our model, $Tmin^{ff'}$ is the minimum separation time between two airplanes.

$$Ta_l^{f'} > Ta_l^{f} + Tmin^{ff'} - M\left(1 - y_l^{ff'}\right) \ \forall f, f' \in F, l \in L(Runway) \tag{13}$$

$$Ta_l^{f} > Ta_l^{f'} + Tmin^{ff'} - My_l^{ff'} \ \forall f, f' \in F, l \in L(Runway) \tag{14}$$

4. Solutions and Simulation Study

Mathematical model has been solved on various sample sizes on CPLEX using OPL interface. Based on the publically available information and Google map, network model of an airport from gates to runways was defined (Figure 1). A simulation models on Arena was used for verification. Simulation model is also used for testing stochastic cases. Small variations from optimality conditions cause significant changes on the objective. In order to increase the robustness of mathematical model, we introduced a safety factors to keep a minimum separation between aircrafts at gates, nodes (intersections at the taxing routes) and runways. Our experiments suggested that while small separation distances are acceptable at the runways, larger separation distance is required at gates.

Figure 1: Network model of an airport from Google Map. Marked locations later manually triangulated

5. Conclusions

In this paper we introduced a conflict free airport operations planning model. In the literature, most taxing planning models focus on routing of aircrafts through a network and determining the arrival and departure times of aircrafts at the intersections. Collision avoidance within airports on the other hand is investigated mostly independently. In this research, we attempt to incorporate both collision avoidance and taxing operations in the same mathematical model. Furthermore, timing constraints are non-time indexed. Traditionally, air-traffic management problems are modeled using discrete time intervals where time is a period and decision are made periodically. In our model, timing variables are real number. Therefore, collision avoidance is sustained at all times. Moreover, testing results in a simulation model enabled us study the impact of various separation distances between aircrafts on stochastic operating conditions.

Acknowledgements

This research has been funded by Natural Science and Engineering Council of Canada.

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Biography

Ali Akgunduz is a Professor at the Department of Mechanical and Industrial Engineering at Concordia University, Montreal, Canada. Prior to joining the faculty, he worked as an Analyst-R&D at the Information Systems Division of United Airlines in Chicago. He earned his doctorate in 2001 from University of Illinois at Chicago in Industrial Engineering and Operations Research, his MBA in 1996 from Illinois Institute of Technology, Chicago and his BSc in 1992 from Gazi University in Ankara, Turkey. Dr. Akgunduz's research interests include airline operations, systems simulation and network optimization. He is a registered professional engineer at Professional Engineers Ontario.

Strategic Alignment and Technology Management

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Abstract

This paper focuses on the method used in FNSS Defense Systems to align technology efforts and investments with company's product strategy. The alignment framework aims to link research and other investments to strategic plan and helps to develop a consensus about the set of needs and the technologies required to satisfy those needs. Besides, this alignment framework also takes the boundary conditions, opportunities and constraints into account, which arise due to the nature of defense industry. Localization and local strategic partnership as well as local university collaborations play an important role for the defense industry and this work also includes the approach related to this factors.

Keywords

Technology management, R&D strategy, defense industry

1. Introduction

As the technologies advances, blast and explosive technologies also create more series threads, and the technical demands on the products increases rapidly. For the land vehicles industry, the market demand also favors competing requirements. For instance, customers value lightweight design due to the increased demand for land and amphibious mobility features, as well as higher levels of survivability due to the fact that the threads are getting more dangerous. Besides these competing technical requirements, small series production dominates and as the new comers to the defense industry are upcoming, cost effectiveness gets more and more significant. In order to address all these competing and challenging requirements and stay competitive in the future, foreseeing the future and managing the technology and technology investments are of crucial importance. The most common approach to manage the future is the technology road mapping [Willyard 1987, Garcia 1997, Phaal 2001].

The main benefit of technology road mapping is to help make better technology management decisions. The aim is to identify critical technologies or technology gaps that must be filled to meet product performance targets. Then, the ways to leverage business decisions must be identified and coordinated through aligning research activities either within a single company or among alliance members [Emden 2003].

This paper focuses on the approach of FNSS Savunma Sistemleri A.S, to determine what to do to increase competitiveness in the future and how to do it in order to reach the demanding goals of the next years.

2. Technology Road mapping

Road mapping is a living process of creating and implementing a roadmap, monitoring, and updating it as necessary by taking input from both market and technology perspectives. A technology roadmap brings different perfectives to a single platform and aims to foresee the future products and the related technologies (see Figure 1).

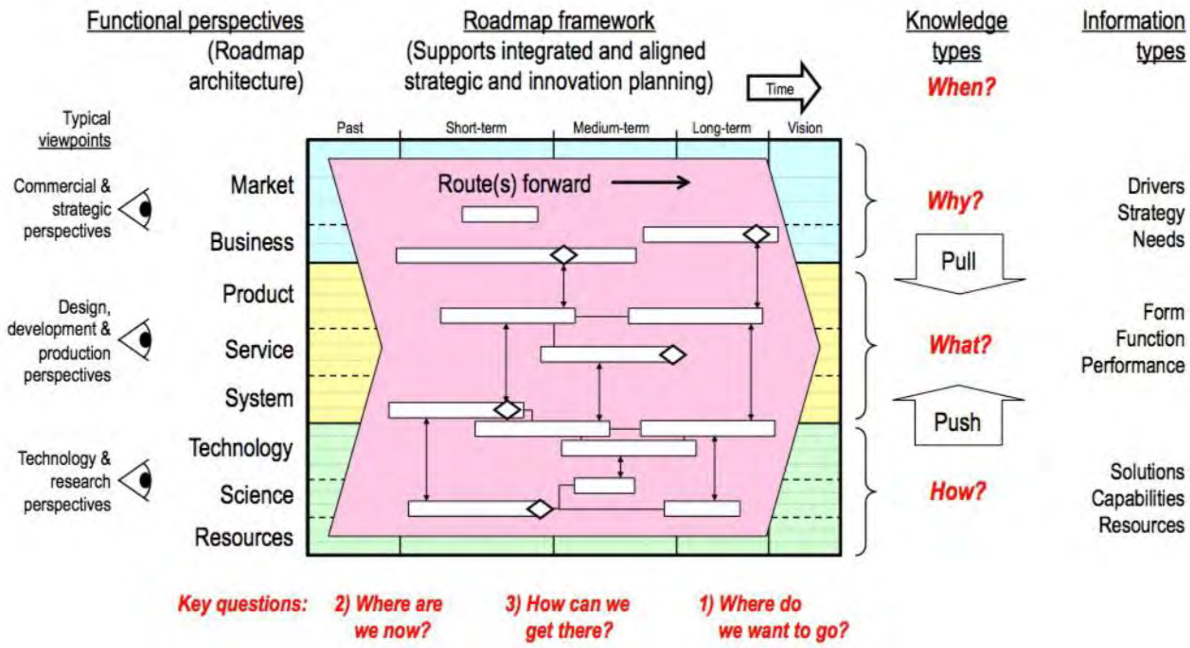

Figure 1: Technology road map chart [Phaal 2015]

There are different approaches and methods of technology road mapping process. For business organizations that sell products directly to consumers, the market pull integration strategy predominates as the aim is to improve existing product lines according to consumer market trends. On the other hand, technology push predominates at some research centers and small and medium-sized enterprises (SMEs), because their focus is on their core competence [Caento 2011]. FNSS Savunma Sistemleri A.S prefers to combine both market pull and technology push approach, putting more emphasis on less risky market pull approach.

A series of analysis is conducted to foresee the technologies needed to capture and execute the upcoming projects in five to ten years. The requirements and customer value, FNSS' capabilities and the competitors status is evaluated to find the areas that has room for improvement. On the other hand, the technologies which can change the market situation, the so-called 'game changing technologies' are also being identified.

The Figure 2 below depicts schematically the concept of FNSS' technology road mapping.

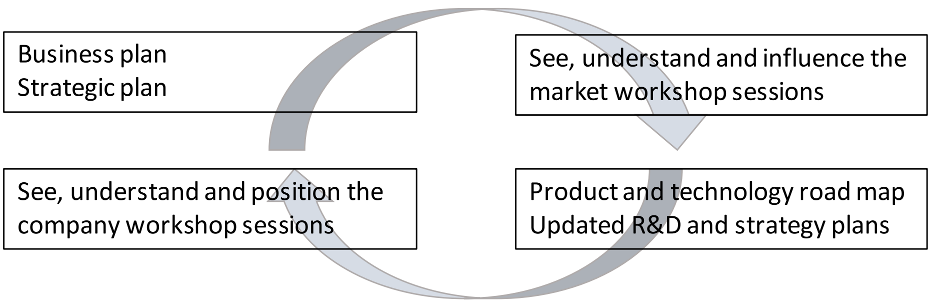

Figure 2: FNSS Approach for technology road mapping

The main output of the technology road map is the identification of the technology gaps, upcoming R&D projects and other R&D investments in terms of human resources and infrastructure. The main benefit of the technology road map is to build consensus on priorities and actions to accelerate the activities to support these priorities.

The strategic alignment process of FNSS brings commercial, strategic, design, engineering, technology development as well as R&D and Engineering perspectives to one page and forms a platform to take different perspectives into account. This alignment framework aims to utilize all resources and means of the company to serve for business' needs and strategy.

The technology road mapping process and alignment efforts can result in the following consequences:

- Identification of critical technologies
- Acceleration of internal R&D efforts for critical technologies development
- The deceleration of internal R&D not-so-important technologies
- Start up of collaborations to acquire external technologies

3. Strategic Partnerships and Alliances

After the needs and gaps are identified, the critical and non-critical technologies must be determined. The core competencies, enabling technologies as well as basic competencies must be identified. After that, the decisions will be taken, how to move forward, with which partners and alliances and by when.

Cooperations with solution and strategic partners are important in achieving delivery in time, reducing costs, as well as enabling access to talents and infrastructure. There may be technology areas, which may necessitate bigger investments that can only be achieved by research alliances, which are also supported by governmental funding and/or cooperation of several OEMs (original equipment manufacturer).

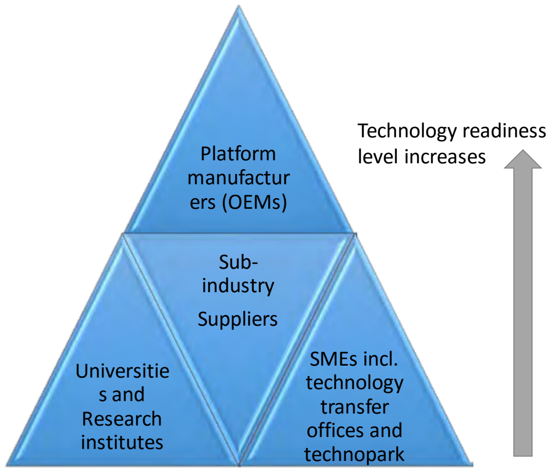

Figure 3: Cooperations with universities, smes and other sub-industry

The Figure 3 depicts the general approach for university, OEM and SMEs (small medium sized enterprises) relationship. In the figure 4, the platform manufacturers are placed on the top of the pyramid, being in cooperation with academic and industrial solution partners. The bottom of the pyramid serves more to conduct research, where the OEMs are responsible to integrate the developed technologies into products. Still, the transition between research and product is very challenging and requires solid cooperations as well as agile personnel, who are able to consider both research and product engineering aspects.

This scheme is valid in general, esp. for companies with smaller product portfolio and/or small series production, since the OEMs with larger product portfolio are known to conduct their own industrial research and technology development as well as technology integration.

Innovation increasingly depends on the ability of university and industry experts to work together across a number of disciplines, such as technology, design and engineering. This may be coarsely one of the ways to handle the gap between technology readiness levels 4 to 6, which are known as ‘valley of death’ in literature (Figure 4).

The “valley of death” is a metaphor used to describe the gap between academic-based innovations and their commercial application in the marketplace [Gulbrandsen 2009]. There are many detailed models to bridge the valley of death [Gulbrandsen, 2009; HC348, 2012]. There are good examples like Fraunhofer Instituts to bridge these gaps. Turkey, as a developing country with limited sme strength, needs also a systematic approach to bridge this gap to be able to compete with the strong competitors.

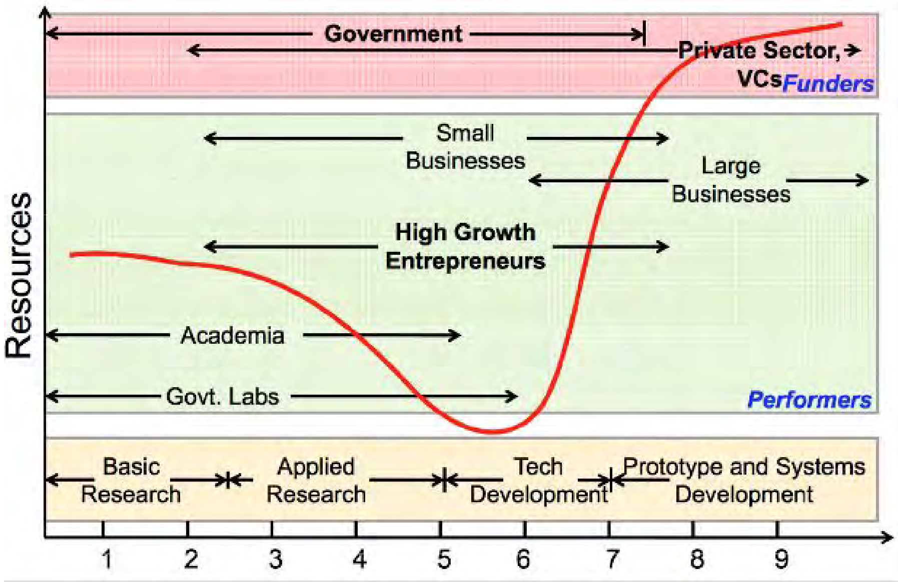

Figure 4: Technology readiness levels and the valley of death [Coyle, 2011]

3.1 University Cooperations

University cooperation is very significant for FNSS Savunma Sistemleri A.S, as this kind of cooperation and partnerships enable company to see the feasibility of some technologies, which has lower technology development readiness level for defense industry.

Creating more strategic industry-university partnerships would improve climate for innovation and introduction of new technologies into products. In Germany there are good examples of strategic academia-industry alliances like Audi's Ingolstadt Institute of TU Munich and GE Global Research located in TU Munich Campus [Edmondson et al. 2012]. Turkey as well as FNSS needs to build a solid approach for university cooperations.

3.2. Cooperations with Sub-industry and Smes

In order for a platform manufacturer to be able to focus on the core competencies and increase speed as well as flexibility, outsourcing of engineering and manufacturing work is indispensable. For the defense industry localization is also another important subject.

Therefore, cooperation with local small and mid-size industry as well as engineering service companies is indispensable. Here, in order to avoid hidden costs and to meet the schedule, the requirement management, its verification methodology as well as design reviews must be managed closely.

Another advantage of strategic partnership is to have access to both skill and talent as well as infrastructure. For some technology areas, big investments are needed in terms of expertise and infrastructure. As land industry works with very small series and high number of variants, such investments are in most cases not profitable. In such cases platform manufacturers are obliged to form sustainable strategic partnerships.

Here different supplier relationship scenarios are possible. Another factor is the governmental grants and other economical facilitators. These factors may also affect the supplier relationship. The FNSS workflow can be seen as depicted in Figure 5.

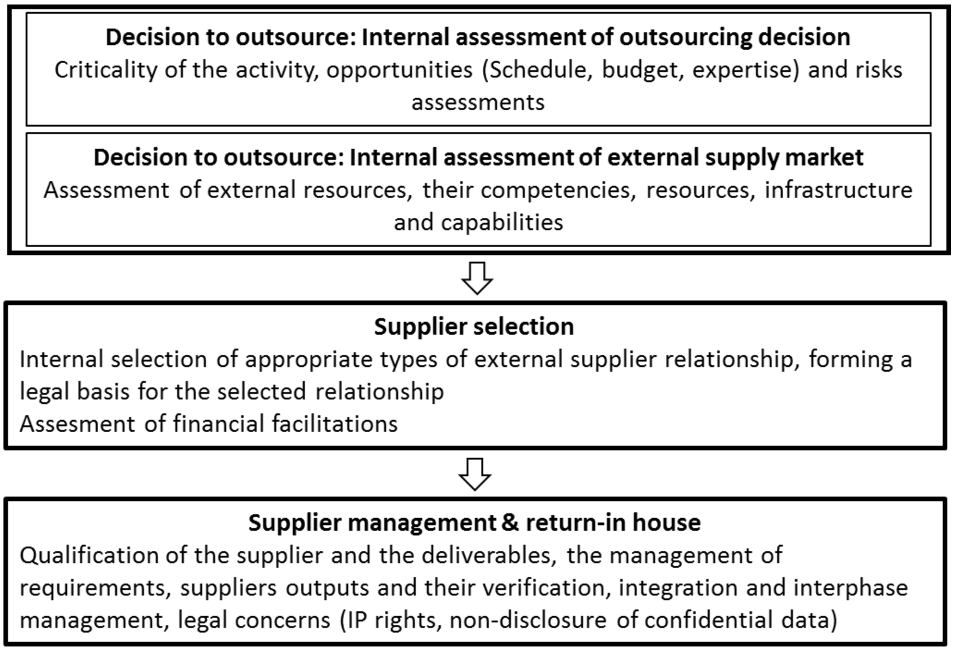

Figure 5: Outsourcing workflow

3.3. Research and Technology Development Alliances

Some technology areas may involve huge investments, which cannot be handled by the internal R&D budgets of one single company. If these technology areas are of higher relevance for several companies and sectors, technology development alliances may be of concern. Excellence centers, research institutes may serve as alliances that may be serving for the technology transfer from invention to product by this way, several local OEMs from different sectors and industries may benefit from the synergy effects and complete the higher technology levels in-house. This approach would enable even competitors benefit from the local resources and infrastructure. Such alliances must be governmentally supported and encouraged.

4. Conclusions

In this work, the technology road mapping process, prioritization of the needs as well as the approach to bridge these gaps are mentioned. FNSS Savunma Sistemleri A.S is a leading defense company, making use of the known technology road mapping and strategic partnership models from literature as well as customizing them to the specific boundary conditions of defense industry.

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Biography

Kıvılcım Ersoy serves as senior lead engineer as FNSS Savunma Sistemleri A.S. She has received her B.Sc. degree from METU, Ankara in 2002, M.Sc. and Dr.-Ing. degrees from Technische Universitaet München, in years 2004 and 2009 respectively. She has more than 13 years of research and technology development experience both from academic and industrial side. Her current working areas include technology roadmapping, industrial research and technology development management.

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Brent Butcher is the Vice President and Assistant General Manager for FNSS. In this position, he provides leadership in the execution of combat vehicle development and production contracts, and works closely with customers in Turkey, Middle East, and South East Asia. Brent has over 15 years of experience in the vehicle industry including more than 10 years in the defense industry. His accomplishments include building multi-functional teams to support corporate-priority pursuits; incorporating program management disciplines throughout various businesses; and establishing a culture in programs that generate innovative solutions to challenging problems. He holds a bachelor of science in Mechanical Engineering from Southern Methodist University in Dallas, Texas and is a graduate of the Executive Leadership Program at the University of Oxford's Saïd Business School.

Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

TOGAF Based Governance Framework Proposition for Technology Management Systems

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Abstract

A computer-based technology management system is needed to manage technology assessment, technology acquisition and technology planning capabilities to shape and accomplish the strategic and operational objectives of an organization. During the design of a technology management intelligence, it has appeared that there has been a need to establish an integrated and systematic approach. Open Group Architecture Framework (TOGAF) provides this systematic approach to the planning, development, implementation and governance of the enterprise architecture. This exploratory paper examines the TOGAF approach to develop a technology management architecture in a product development organization. The paper discusses the development and proactive governance of the technology management architecture from various perspectives such as architecture capability, architecture development, transition planning and architecture implementation. The paper presents a TOGAF based governance framework for the technology management system in an organization that develops software-intensive systems. The framework supports an iterative approach in the architecture capability, architecture development, transition planning and architecture implementation phases. The implementation governance phase can deal with multiple projects simultaneously. Therefore, the framework suggests applying agile system development principles to the projects that develop and deploy the architecture-compliant technology management solutions. Technology management enterprise architecture requires an adequate organizational structure to support TOGAF based governance activities.

Keywords

Technology management, enterprise architecture, TOGAF, organizational structure, governance framework

1. Introduction

Technology management is defined as collaboration of “engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization” (National Research Council, 1987). Technology utilization, knowledge management, technology acquisition, technology integration, technology assessment and technology planning and forecasting are some of technology management activities (Çetindamar et al., 2006). The common feature of all these activities is that they require both data and domain-specific decision-making algorithms and methods. Technological advances in computer-based Information Technologies (IT) facilitate technology management processes (Linn et al., 2000). IT enables organizations to establish a more robust, resilient, intelligent and automated processes for a technology management framework. On the other hand, organizations desperately need an architectural framework when implementing and maintaining an enterprise-wide technical infrastructure for the support of technology management system.

The management of technology management activities requires a different approach to achieving interoperability between the technology management system and the rest of the business. An integrated and systematic approach is needed, where development, implementation, and operation of the system is guided by strategic and tactical business objectives. More importantly, technology management system can be continuously updated and extended by new requirements of end users. In such circumstances, there is a need for an effective governance framework to establish and sustain a technology management environment. Open Group Architecture Framework (TOGAF) provides this systematic approach to the planning, development, implementation and governance of the enterprise information architecture (The Open Group, 2011). In this paper, TOGAF approach is examined in order to develop technology management architecture in a product development organization. The development and proactive governance of the technology management architecture is discussed from various perspectives such as architecture capability, architecture development, transition planning, and architecture implementation. Consequently, the paper proposes a TOGAF based governance model for the technology management system in an organization that develops software-intensive systems. The organizational structure and business processes should support the new approach. Therefore, the paper also focuses on the need for organizational change.

2. Technology Management System

The Management of Technology (MOT) discipline encompasses large number of disciplines including, but not limited to, project management, strategic management, innovation theory and technology philosophy (Drejer, 1997). According to Huijiong (1993), planning for the development of technology capabilities, identifying key technologies, making buy or make decisions and establishing institutional mechanisms for management of the development of technology capabilities are four fundamental technology management activities (Liao, 2005). Çetindamar et al. (2009) grouped technology management activities under six main headings: Identification, selection, acquisition, exploitation, protection and learning. While identification deals with search, auditing, data collection and intelligence processes, selection focuses on decision-making activities to assess or appraise capacity based on relevant strategic issues. Acquisition is another decision-making process that creates three basic choices: Technologies might be developed internally, in some form of collaboration, or acquired from external developers. Linnn et al. (2000) introduced an object-oriented intelligent management system for technology management in order to enhance automation in technology management. The system is organized into a two layers, namely, management layer and operation layer. While the management layer administrates the overall system activities, the operation layer manages domain-specific expert system activities, such as technology development planning.

Technology assessment is a vital part of technology management. It aims to establish an early warning system to detect, control and direct technological changes to maximize benefit (Cetron,et al., 1972; Van Den Ende, 1998). Chestnutwood and Levin (1999) introduced The Technology Assessment and Management (TeAM) methodology that aims to support decision makers by providing various tools to determine product replacement, technology insertions, and upgrade decisions over the life of the system. Technology capability is another important part of technology management. Technology capability is the capability to make effective use of technical knowledge and skills (Jin & Zedtwitz, 2008). Panda and Ramanathan (1996) classified technological capability under three headings, namely, strategic technological capabilities, tactical technological capabilities and supplementary technological capabilities. On the other hand, Asian and Pacific Center for Technology Transfer (1989) developed a technological capability assessment methodology called Technology Atlas. Technology Atlas evaluated the capability of technology under four headings: Technoware, Infoware, Humanware and Orgaware (Alizadeh, 2012).

In this research, a Technology Management System (TMS) is introduced based on basic requirements of technology management principles. TMS illustrated in Figure 1 is an integral part of computer-based information system that supports technology management related business processes, information flows, data analytics and reporting in a product development organization. TMS includes technology capability assessment system, technology acquisition system, technology assessment system and technology planning and forecasting system. It aims to support business decision-making activities in technology management domain. TMS is not a stand-alone business entity. It shares data or applications with other systems such as Human Resources (HP), production, product development (PD) and Business Development (BD). It also provides user interfaces that allow the user to manage activities and events related to technology management. All groups in the Technology Management Enterprise (TME) should be involved in the development, maintenance and operation of the information environment.

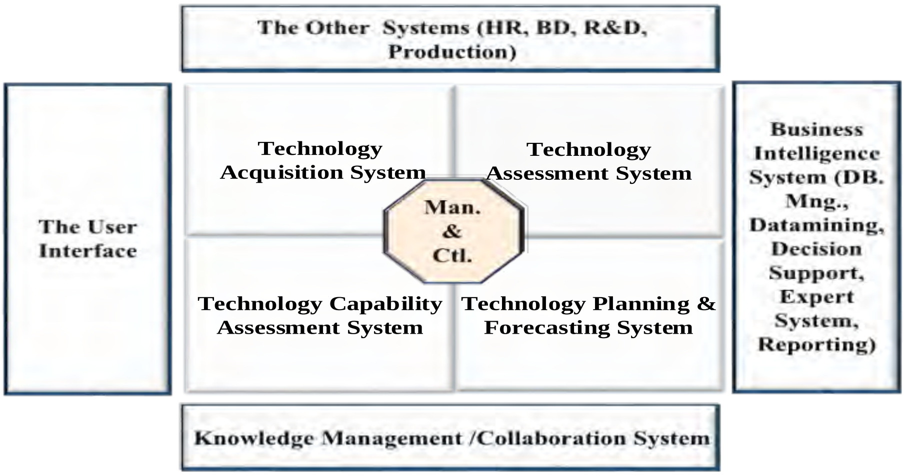

Figure 1: Computer-based technology management system

3. Why Do We Need The TOGAF Framework?

A firm should have the ability to integrate commercial and technological functions in order to establish effective technology management approach (Phaal et al., 2006). In fact, technology management requires an integrated perspective that aligns technology strategy with business strategy and coordinates the research, development, production, human resources, marketing and other functions of the firm (Drejer, 1997). A technology or product development organization requires a framework that covers a formal description of the TMS with its components and interfaces, a set of guidelines, templates and standards which are required to establish and maintain the TME architecture practice within the organization. The framework must ensure that TMS sustains and extends the strategies and objectives of the organization. It must help the organization keep up with emerging opportunities. The framework must create an environment that identifies essential software applications and hardware changes in order to support new requirements arising from current and future business needs. This paper applies the TOGAF approach in order to address these three fundamental issues (compliance with the strategy, management of change and management of requirements) explained above. The TOGAF is used as a framework to develop and maintain enterprise architecture with TMS solutions. It places the requirement management process at the center of Architecture Development Method (ADM) in order to maintain traceability between requirements and the architectural structures (Engelsman et al., 2010).

The literature review shows a limited number of studies on the TOGAF framework. Kabzewa and Müller (2010) applied the TOGAF ADM to a large-scale SOA-based research project in order to support the governance proposes in the context of a service marketplace. Chaczko et al. (2010) presented the smart hospital system solution that used the TOGAF ADM. While Zadeh et al. (2012) analyzed the business principles of the TOGAF according to the principles of cybernetics, Leist and Zellner (2006) evaluated the TOGAF and other well-known architecture frameworks regarding their contribution to support architecture development projects. Unlike the studies in the literature, this paper applies the TOGAF framework to the development and implementation of technology management processes.

4. The TOGAF Based Governance Framework for TMS

During the design of a computer-based technology management system, the product development organization needed organizational structures, processes, principles and standards that ensure that the TME sustains the strategies of the organization and accomplishes the needs of end users and stakeholders. This paper uses the TOGAF ADM lifecycle to develop and manage TMS enterprise architecture. Figure 2 shows phases of the TOGAF ADM lifecycle. The ADM starts with a preparation and initiation phase called Preliminary Phase. TMS enterprise, architecture principles and the relationship between other management frameworks are defined in Preliminary Phase. Enterprise in technology management concept is an organization that has established a culture of technology management in the company, implemented computer-based technology management system and continuously managed the technology management related processes and activities. Technology management activities must be aligned with the business objectives. Data which is retrieved, processed, used and stored in TMS is an important asset and needs proper management.

TME architecture development lifecycle is started with "Request for Architecture Work" document from sponsor to TME executive. Architecture Vision phase identifies the key stakeholders and their objectives. TME retrieves data from the HR, R&D and production departments to evaluate dynamic capabilities in technology and product development; from the marketing and BD departments to assess and plan the key technologies and to make proper technology acquisition decisions. Therefore, the HR, R&D, production, marketing and BD departments are the key stakeholders of TME. This phase also identifies the key business requirements to be taken account during the development of business, information system and technology architectures. Assessing performance of business capability based on technology development capability, selecting the appropriate technology acquisition mode based on business capabilities, tracking and assessing current and future technology to be used as a critical asset in the growth of business, planning technical evaluation of the product line or product platform in the business and minimizing the TMS OPEX (OPerating EXpense) are some of the key business requirements.

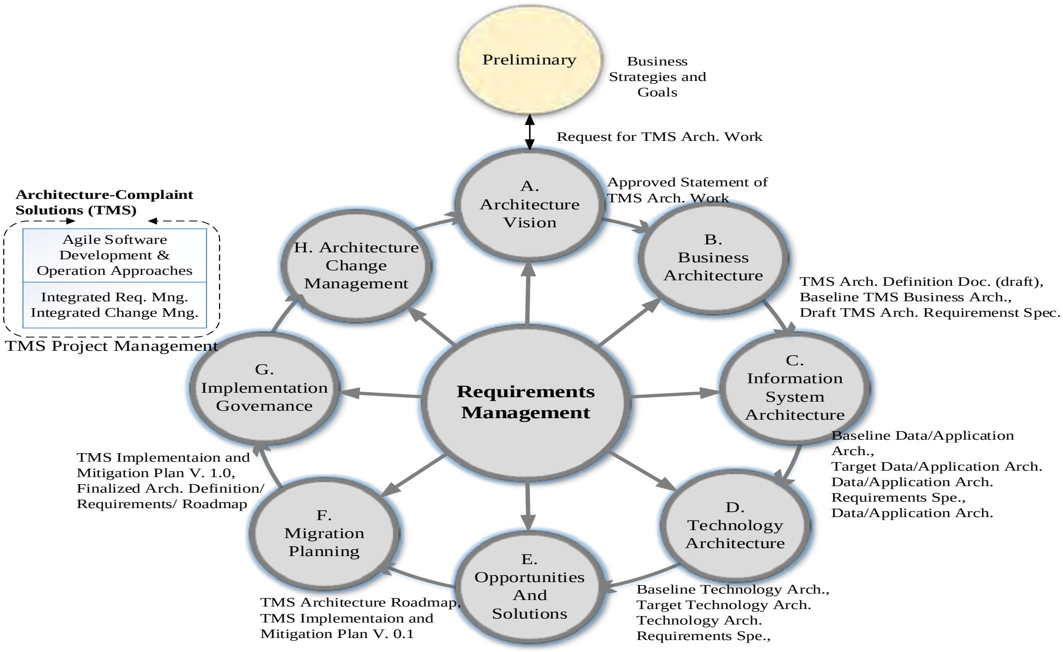

Figure 2: The TOGAF ADM lifecycle (The Open Group, 2011)

The TOGAF framework supports four architecture domains, namely, the business architecture, the data architecture, the application architecture and the technology architecture. The architecture development phases follow the same steps: 1) select reference models, viewpoints and tools, 2) develop baseline architecture description, 3) develop target architecture description, 4) perform gap analysis, 5) define candidate roadmap components, 6) resolve impacts across the architecture landscape, 7) conduct formal stakeholder review, 8) finalize the business architecture and 9) create architecture definition document (The Open Group, 2011). The Target Business Architecture of TMS is developed based on the information given in the Architecture Vision, including business requirements and business scenarios. For each subsystem of TMS, the high level business requirements are decomposed into the more detail lower level requirements and business models are created from the business scenarios given in the Architecture Vision document. The business strategy, governance, organization, key business processes and information are described in the business architecture domain. Business architecture phase aims to define the requirements of the following domains. The Business Architecture of TMS and the Architecture Vision are used to develop the Target Data Architecture, the Target Application Architecture and the Target Technology Architecture.

The TSM architecture roadmap gives a high level view of the target architecture and presents work packages in a timeline diagram. The Implementation and Migration Plan provides the activities necessary to realize the TSM architecture roadmap and the schedule of TMS development projects. The TMS architecture roadmap and the implementation and migration plan are generated during the transition planning phases.

The TOGAF based TMS governance framework aims to develop and maintain a technology management intelligence dealing with knowledge management, technology capability assessment system, technology acquisition system, technology assessment system, technology planning and forecasting system and management and support system activities. The figure 3 illustrates the TOGAF based governance framework for TMS enterprise. The framework suggests an iterative approach in the architecture capability (Phase A), architecture development (Phase B, C & D), transition planning (Phase E & F) and architecture implementation (Phase G & H) phases. Each cycle can run several iterations in order to complete business requirements and business scenarios and to develop an adequate and sufficient business, data, application and technology architectures required for the implementation. The implementation governance phase can carry out multiple projects simultaneously to develop and deploy the architecture-compliant TMS solutions. The framework hardly suggests applying agile system development principles and practices to the implementation governance phase. This iterative and incremental development style brings some advantages such as continuous improvement, rapid and flexible respond to change and early delivery.

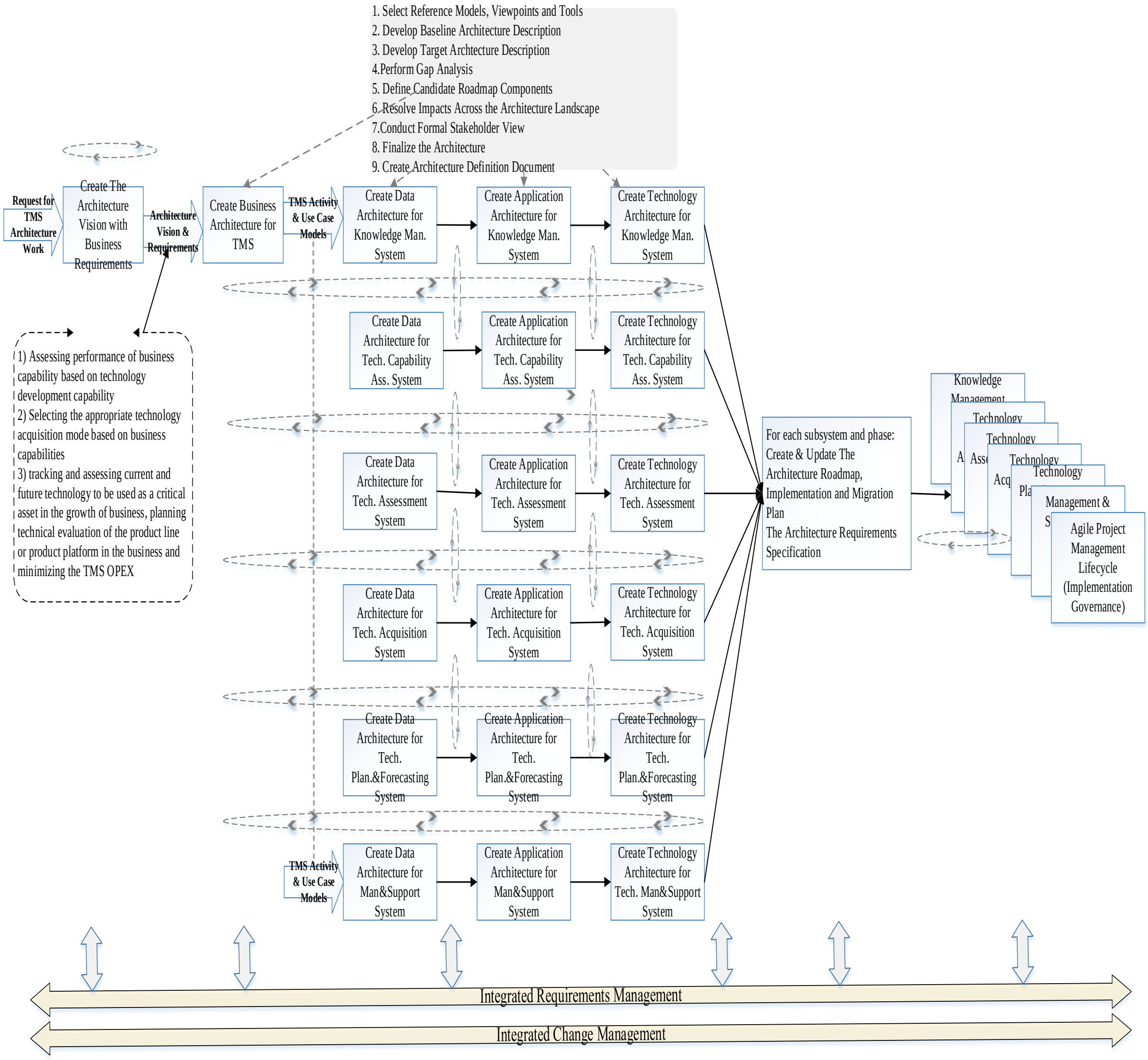

Figure 3: The TOGAF based governance framework for TMS

Architecture change management phase recognizes not only bottom-up changes that are occurred during the development, maintenance and operations of TMS applications but also strategic, top-down directed changes to influence TMS capability (The Open Group, 2011). The framework applies the defined change management processes, environment and tools in the organization to manage changes. It promotes an integrated change management approach to combine and manage changes in the architecture capability, architecture development, planning and architecture implementation phases. The framework also uses the defined requirement management processes, environment and tools in the organization to manage architectural requirements identified during the execution of each ADM phase. The requirements management and change management processes work together to ensure the proper management of change in architectural requirements.

5. Organization Structure of TMS Architecture Governance Framework

TMS enterprise architecture created, managed and controlled by TOGAF ADM requires an adequate organizational structure in order to support all governance activities. Developing and operating the TMS enterprise architecture is not a solitary activity. TME needs to cooperate with the sponsor who is responsible for financially authorizing the TMS architecture, creating Request for Architecture Work and approving the final work. TME also cooperates with the end users and the stakeholders who are responsible for reviewing the outputs of each ADM phase. TME executive is responsible for managing and leading across functional teams of TMS architects, IT technical support personnel, system and software engineers and domain experts. TME executes assign tasks and responsibilities of the functional team members. They have responsibility for the overall success of the entire enterprise. The TMS architecture board members consists of 1) architects for enterprise architecture, business architecture, data architecture, application architecture and technology architecture; 2) project managers; 3) system and software engineers; 4) IT technical support personnel and 5) domain experts. The roles of Architecture Board members are grouped under seven categories: Decision-making, architect, project manager, IT support, system and software developer, reviewer and expert. Board members may take differing roles and responsibilities depending on their technical and domain experience. The fundamental relationship among sponsor, end users, stakeholder, the TME executive and architecture board is illustrated in Figure 4.

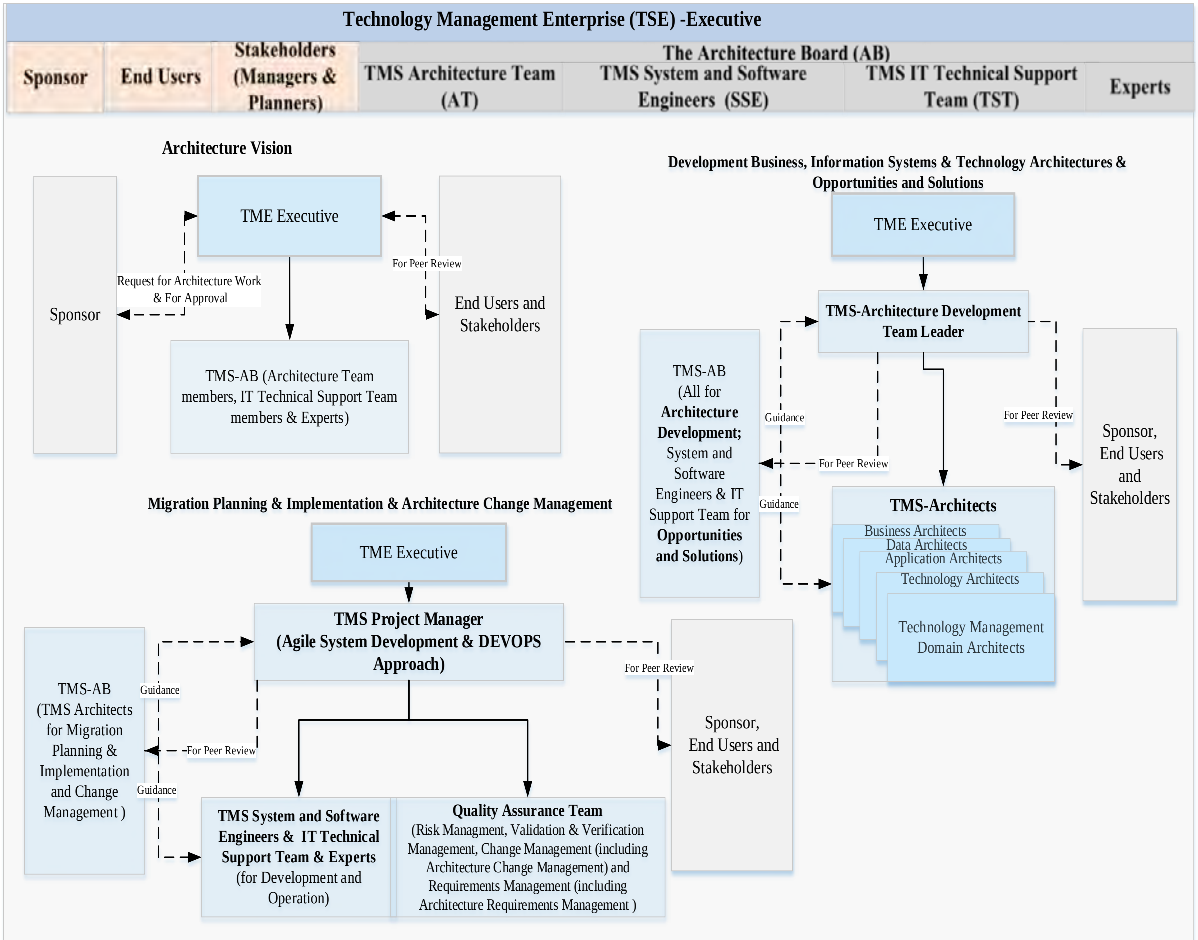

Figure 4: Organization structures of TMS architecture governance framework

5. Conclusions

The paper presented a computer-based TMS that consisted of knowledge management system, technology capability assessment system, technology acquisition system, technology assessment system and technology planning and forecasting system, and management and support system. TMS supports all business decision-making activities in technology management domain. The management of technology management activities requires an integrated and systematic approach to sustain the strategies and objectives of the organization. The paper examined the TOGAF approach to establish a technology management architecture in a product development organization. The proposed framework uses an iterative approach in the architecture capability, architecture development, transition planning and architecture implementation phases. It can perform several iterations in each cycle in order to develop business, data, application and technology architectures. The framework also recommends applying agile system development principles to the system and software implementation (implementation governance) phase. The framework also suggests the integrated change management and integrated requirements management processes. The requirements management and change management processes must work together in order to ensure the proper management of change in architectural requirements.

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Biography

Nermin Sökmen serves as a senior research engineer in Informatics and Information Security Research Center (BİLGEM) at the Scientific and Technological Research Council of Turkey (TUBITAK). She graduated with a BS from Istanbul Technical University in Electronics and Communication Engineering, a MBA from the Boğaziçi University, and a PhD from Istanbul Technical University in Management Engineering. She worked in various positions at the Switching and Routing R&D Department of Alcatel Teletaş until 2002. She has undertaken important tasks and responsibilities for/at the R&D department, quality, business development and technology management units, in the field of telecommunication and security of ICT sectors as of 1991. Her current research interests include Software Product Development, Technology Management, IT Project Management, Data Analysis and Modelling, Business Intelligence, Enterprise and Software Architecture.

Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A Strategic Supply Chain Network Design Evaluation Based On Mixed-Integer Linear Programming

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Abstract

The cost pressures in the paint industry require cost reductions for manufacturers to remain competitive. Intrinsic characteristics of construction materials products and processes along with growing sustainability concerns lead to the need for decision support tools that can integrate economic considerations with quality preservation and environmental protection in construction material supply chains. Based on this the need for a better supply chain network design is inevitable, consequently logistics constraints are subjected to review. In this study a Mixed-Integer linear programming (MILP) model is developed for examining of changes in profitability based on the real-life data and the results have been evaluated. The overall optimization is achieved using mathematical programming for modeling the supply chain functions such as location, distribution functions and transportation mode selections. Then, the supply chain model is formulated as a minimization problem for costs and environmental impacts. Herein, the solution is the flow of goods in global supply chain environment in different routes over one year. As coordination plays crucial role in supply chain management, findings of this solution for omitting of dealers and opening new distribution centers (DC) help to extract managerial insights.

Keywords

Supply chain management, network design, mixed integer linear programing, Full Truck constraint, strategic planning

1. Introduction

Supply chain management has become a strategic issue for any company looking to meet targets in terms of economic competitiveness, time and quality of service especially in an economic environment characterized by the globalization of trade and the acceleration of industrial cycles. The trade press is replete with examples of logistics network configuration, re-configuration, re-organization, mergers, outsourcing, and so on. These developments have been influenced by successive trends in the economy and society resulting from computerization, increased complexity of trade flows, increased competition and certainly not least, sustainable development. Thus the strategic design and planning of logistics networks is a topic that is becoming more important for businesses and researchers alike (Eskandarpour, Dejax, Miemczyk, & Peton, 2015). Modern supply chains have evolved into highly complex structures with multiple sourcing layers, planning levels, multimodality and extended information exchange at every link of the chain (Sitek & Wikarek, 2015). Because of interdisciplinary nature of supply chain network design (SCND) each business has a unique value stream. Different factors causing different approaches of management, strategical decisions, logistics and solutions based on operations research.

Supply chain management (SCM) centers around coordination among various members of a supply chain comprising manufactures, distributers, wholesalers and retailers (Lee, Padmanabhan, & Whang, 1997). So there is a stream that is adding value to the raw material from point-of-origin to the point-of-consumption by producing, shipping, moving and storing. Meanwhile, **successful supply chain management requires cross-functional integration and marketing must play a critical role**. The challenge is to determine how to successfully accomplish this integration (Lambert & Cooper, 2000). Regarding the scope of decisions there are three levels: strategic, tactical or operational corresponding to long, medium and short time horizon respectively. Ahumada and Villalobos (2009) identified activities such as financial planning and network design as strategic;

the harvest planning, crop selection and scheduling and labor as tactical; and activities such as production scheduling, transportation planning and storage as operational. Such a classification might become a bit difficult when dealing with activities moving between strategic and tactical decisions, or between tactical and operational (Soto-silva, Nadal-roig, González-araya, & Pla-aragones, 2015).

Enterprises comprise several functions, such as production, marketing, sales, human resources, logistics, safety and environment, which interact with each other. As a result, decision-making becomes highly challenging in the alignment of decisions to support the success of business goals (Munoz, Capon-Garcia, Lainez, Espuna, & Puigjaner, 2013). Supply Chain Network Design (SCND) is also the discipline used to make decisions to open/close supply, production, distribution or sales facilities by optimizing overall profit and cost. Facility location is and has been a well-established research area within Operations Research. Numerous papers and books are witnesses of this fact. As a consequence, facility location models have been gradually proposed within the supply chain context (including reverse logistics), thus opening an extremely interesting and fruitful application domain. There are naturally several questions which immediately arise during such a development, namely: (i) what properties does a facility location model have to fulfill to be acceptable within the supply chain context? (ii) Are there existing facility location models which already fit into the supply chain context? (iii) Does SCM need facility location models at all (Melo, Nickel, & Saldanha-da-Gama, 2009)?

To have sustainable supply chain network in addition to optimize distances, times or costs between customers and facilities, we need to reduce the premiums payments to the dealers that are benefitting from lack of connections between manufacturing and retailers with making strategic decisions. Possible questions to be answered are: (i) which distribution center should be used (opened)? (ii) Which customers should be serviced from which facility (or facilities) so as to by-pass the dealers? In addition to these generic constraints an extra constraint must ensure the Full Truck shipments from manufacturing facilities to distribution centers.

In this paper we are to make a strategic decision for redesigning or not a supply chain network for a dye works, trying to get rid of dealers and cut off premiums payments. Also we will try to avoid no added value direct deliveries to the customers aiming to save of almost twenty percent of the company's total transport burden. The main idea of this strategic plan is to find an economic argument to open its own distribution centers based on comparison between existing and new SCN. Furthermore, Full Truck transport to distribution centers considered as an additional necessity constraint for this problem.

Section 2 covers a comprehensive literature review adopted for the collection of research papers and compares our work with existing papers on related topics. The involved methodology and solution technic for a SCND problem will be described in section 3. Section 4 and 5 are defining a case study as a real-life problem with the mathematical modelling and problem solution approach. A mixed integer linear programming models is proposed for the design of a logistic network. The innovative aspects of this study are: the assumption of a dynamic, multi-product environment and the Full Truck constraint. Finally, in Section 6 we conclude and suggest a number of future research directions.

2. Literature review

Facility location theory is the most important base that developed mathematical models of network design. Recent literature reviews on supply chain management and facility location are introduced by Arabani and Farahani (2012), Van der Vaart and van Donk (2008), Gebennini et al. (2009) and Melo et al. (2009). This Literature leads us to a large amount of researches and technics for designing and control of complex distribution systems (Ustundag & Budak, 2015).

The supply chain encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain. Supply chain management (SCM) is the integration of these activities through improved supply chain relationships to achieve a sustainable competitive advantage (Seuring & Müller, 2008).

As only papers dealing with supply chain management are taken into account, it is logical that economic issues are addressed. Most often, total cost or net revenue is taken as indicators. Yet, there are a number of papers not providing insights into what kind of economic goals is pursued. This holds for a first set of papers that mainly follow a life-cycle assessment (LCA) approach (Sonesson & Berlin, 2003). Often, such papers compare different alternatives toward their environmental performance (Edwards, McKinnon, & Cullinane, 2010; Ferretti, Zanoni, Zavanella, & Diana, 2007). In a number of cases, the current economic situation is (inherently) seen as a kind of baseline for evaluating alternatives on their environmental impact (Seuring, 2013).

Schmidt and Wilhelm (2000) provide an extensive definition of the operational, tactical and strategic decision levels. They classify the reviewed literature according to these decision levels and discuss modeling issues in the remainder of their work. The authors agree that these three decision levels interact and that a unified approach is necessary for the design of a competitive global supply chain (Lemmens, Decouttere, Vandaele, & Bernuzzi, 2016). Meixell and Gargeya (2005) reviewed decision support models for the design of global supply chains, and assessed the fit between the research literature in this area and the practical issues of global supply chain design. Their review dimensions is (1) decisions addressed in the model, (2) performance metrics, (3) the degree to which the model supports integrated decision processes, and (4) globalization considerations. They concluded that although most models resolve a difficult feature associated with globalization, few models address the practical global supply chain design problem in its entirety (Meixell & Gargeya, 2005).

An alternate term for ‘‘supply chain design’’ is ‘‘supply network design’’, used by some authors to signify that supply structures are often more complex than that suggested by a chain (Meixell & Gargeya, 2005). Network design mathematical models traditionally aimed at minimizing cost or maximizing profit, with very little consideration of environmental objectives and constraints (Ilgin & Gupta, 2010). The most recently published literature review on SCND, is the work of Farahani et al. (2014) which focuses on competitive SCND. The competition models are out of the main scope of our research. The authors classify the literature according to the (1) network characteristics and SCND decisions, (2) performance measures, (3) uncertainty considerations and (4) solution approach. They distinguish the different performance measures into economical considerations, environmental considerations, social considerations, agility considerations and uncertainty considerations and relate the recently new emerged paradigms in the field of Supply Chain Management (SCM) to these different considerations (lean SCM, sustainable SCM, green SCM, responsive SCM and risk management in SCM) (Lemmens et al., 2016).

Different levels of a supply network has unique dynamics, as Archetti and Speranza (2016) mentioned at their work, to design an effective supply network logistic issues should be considered. Logistics management is the part of supply chain management that plans, implements, and controls the forward and reverse flow and storage of goods, services, and related information between the point of origin and point of consumption in order to meet customers' requirements. Logistics comprises all the activities related to the functioning of a production–distribution system. Such activities are linked and need to be coordinated to guarantee a good system performance. This concept is widely recognized and has advanced significantly with the advent of the supply chain management concept. However, the most common practices adopted have been based on decomposing the system in parts and handling the single parts independently or sequentially. The main reason for this is related to the fact that integration is very difficult to pursue, often leading to extremely complex management problems. On the other hand, decomposition leads to worsening of the system performance. Also scientific research has traditionally adopted a decomposition approach of the system in parts and then invested efforts to optimally solve the problems arising in each single part (Archetti & Speranza, 2016).

Ding et al. (2004) are saying in their text that ``Production-Distribution network design is a critical decision that has significant impacts on a supply chain`s long term performances. Supply chain dynamics, such as demand fluctuation, and transportation instability, are omitted in most mathematical models due to tractability`` (Ding, Benyoucef, & Xie, 2004). Based on these, open/close decisions for distribution centers has very important effects on efficiency of designed supply chain network and logistics policies. Sharifzadeh et al. (2015) developed a mixed integer (piece-wise) linear program (MILP) to determine the optimal supply chain design and operation, under uncertainty (Sharifzadeh, Garcia, & Shah, 2015). Meanwhile, some supply network designers are interested about their designed network`s sustainability based on sensitivity analysis beside cost/profit optimization (Le & Lee, 2011). As Govindan et al. (2014) that investigated impact of supply chain management practices on sustainability. This approach will help the companies and their respective SCs to reduce their business wastes while it increases value to the customer, sustain their operations and overcome disruptions, and at the same time to reduce the negative environmental impacts (Govindan, Azevedo, Carvalho, & Cruz-Machado, 2014). This paper aims to enhance the sustainability of a real-life supply network by optimization techniques. The results from this experiment can help in determining the best transportation routes, shipment quantity, and transportation modes. Specifically, the results propose a new configuration for designing global supply chain for the case company that could minimize economical and environmental impacts problems simultaneously.

3. Problem Definition and Solution Approach

One can derive the four goals for supply chain network optimization problem as: (i) All demands must be covered by distribution center. (ii) Investment goals for opening new sites considering fix costs. (iii) Investment goals for opening new distribution centers considering fix costs. (iv) Supply costs goals (Ustundag, Budak, Sarvari, & Oner, 2014).

The cost pressures in the paint industry require cost reductions for manufacturers to remain competitive. Construction material supply chains are a fruitful area of cost reduction opportunities because (1) they represent a significant portion of the total cost to serve customers, (2) they constantly change, and (3) their complexity often hides a lowest cost option (Ferrio & Wassick, 2008). The decisions involved in managing a supply chain range from the tactical, such as detailed production scheduling, to the strategic, such as the number and location of production facilities. There are a large number of variables that affect these short- and long-term decisions. Likewise, there are myriad costs that are encountered in supply chains including transportation costs imposed by traders, and partial patch carrying costs just to name a few.

A dye works plans to design a new strategic supply chain network to get rid of dealers and cut off premiums payments. Beside premiums, some dealers are imposing firm, to direct deliveries to the customers and this consists of almost twenty percent of the company's total carrying load. The main idea of this strategic plan is to open its own distribution centers. As shown in figure 1. firm is interested about prospect distribution centers for two production source. Direct ship for partial carrying is prohibited, and replenishment from production sources to the distribution centers are just Full Trucks. Furthermore, Full Truck transport to distribution centers considered as an additional necessity constraint for this problem. The aim of this paper is to compare current and new networking system with the sense of feasibility.

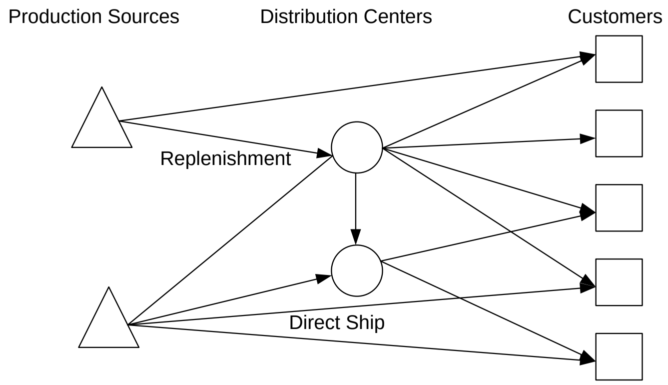

Figure 1. Firm`s supply chain network problem representation

Geoffrion and Graves (1974) presented some of the earliest work on approaching the design problem as a MILP. They focused on the design of a distribution system with a single echelon of DCs connecting production plants to customer zones. The objective was to minimize the sum of transportation costs and DC operating costs. Their model included constraints for production and DC capacities and a variety of other constraints related to the allowable configuration of the network. Fixed and variable costs at DCs were included (Ferrio & Wassick, 2008). Transportation costs and mode of transport selection were not specifically modeled, so the main cost opportunities identified were those associated with DC selection and single sourcing customers from a DC. They presented practical considerations such as model validation and sensitivity analysis to parameter changes. They also discussed the selection of changes to be implemented, but their approach is limited to scenario testing.

This real-life application of supply chain network design may help us to compare our present trader based supply network which has been formed of two permanent production sources and plenty of traders whole over Turkey, with a proposed DC based supply network with 29 prospect distribution center cites. Table 1, Table 2, Table 3. Are illustrating a partial catch of current supply chain parts and entities such as product types, shipping types, departures, destinations, customer demands, factories capacities and DC`s capacities.

Table 1: A partial catch of supply chain network inputs

Departure (km)	Destination	Product	Shipping Type	Shipping Cost (TL/Ton)	Distance
F_GEBZE	D_ADANA	I. Material	Partial	357	828
F_GEBZE	D_ANKARA	Paint	Full Truck	53	342
F_GEBZE	D_ANKARA	Paint	Partial	324	342
F_GEBZE	D_ANKARA	Insulation	Full Truck	93	342
F_GEBZE	D_BALIKESİR	Paint	Full Truck	52	279
F_GEBZE	D_BALIKESİR	Paint	Partial	1.325	279
F_GEBZE	D_BALIKESİR	Insulation	Full Truck	61	279
F_GEBZE	D_BALIKESİR	Insulation	Partial	295	279
F_GEBZE	D_BALIKESİR	Commercial	Full Truck	57	279
F_GEBZE	D_BALIKESİR	Commercial	Partial	M	279
D_DÜZCE	M_BARTIN	Paint	Partial	68	203
D_VAN	M_BATMAN	Paint	Partial	164	298
D_VAN	M_BATMAN	Insulation	Full Truck	M	298
D_VAN	M_BATMAN	Insulation	Partial	188	298

Table 2: A partial catch of customer demand inputs

Customer (Ton/Year)	Product	Shipping Type	Demand
M_ADANA	Paint	Full Truck	520
M_ADANA	Paint	Partial	234
M_ADANA	Insulation	Full Truck	859
M_ADANA	Insulation	Partial	400
M_ADANA	Commercial	Full Truck	4
M_ADANA	Commercial	Partial	97
M_ADANA	I. Material	Full Truck	275
M_ADANA	I. Material	Partial	730
M_ADIYAMAN	Paint	Full Truck	247
M_ADIYAMAN	Paint	Partial	652
M_ADIYAMAN	Insulation	Full Truck	322
M_ADIYAMAN	Insulation	Partial	9
M_ADIYAMAN	Commercial	Full Truck	53
M_ADIYAMAN	Commercial	Partial	14

Table 3: A partial catch of productıon sources and prospect DC capacıties per year

Factory	Product	Capacity(Ton/Year)
F_GEBZE	Paint	2000000
F_GEBZE	Insulation	2000000
F_GEBZE	Commercial	2000000
F_GEBZE	I. Material	2000000
F_KAYSERİ	Paint	0
F_KAYSERİ	Insulation	2000000
F_KAYSERİ	Commercial	2000000
F_KAYSERİ	I. Material	2000000

DC Sites	Capacity(Ton/Year)
D_ADANA	2000000
D_ANKARA	2000000
D_ANTALYA	2000000
.	.
.	.
.	.
D_SAKARYA	2000000
D_ISPARTA	2000000

4. Basic optimization model

This section describes the translation of the supply chain structure described in Section 3 into a complete mathematical model.

4.1 Network entities

Underpinning our model is the concept of a customer record which contains the information on finished product demand. The customer demand record can be uniquely identified below attributes:

- Distribution center location
- Distribution center capacity
- Customer Location,
- Demand Quantity,
- Product Name or ID,
- Mode of Transport.
- Shipment costs

4.2 Mathematical model entities

A much more general form of the DC location model needs to be considered if the entire supply chain network from factory to customer is to be designed. We considered a supply chain in which factories send products to DC`s that supply customers as shown in Figure 1. Location and capacity allocation decisions have to be made for DC`s. Multiple DC`s may be used to satisfy demand at a market. It is also assumed that partial shipment from factories is prohibited as well as direct replenishment to the customers, unless Full Truck carrying. The model requires the following inputs:

i = number of factory locations

j = number of DC locations

p = *number of* product types

t = number of transportation types

k = number of customer locations

K_{ip} = potential capacity of factory i. to supply product p.

W_j = DC capacity at site j

D_k = demand from customer k

F_j = fixed cost of locating a DC at site j

Define the following decision variables:

$y_{\mathrm{j}} = 1 \text{ if DC is located at site j, 0 otherwise}$

$$\mathrm{t} = \begin{cases} 1 = \text{full truck} \\ 2 = \text{partial} \end{cases}$$

Partial shipment (t=2) from production sources to any DC or customer is prohibited using M penalties as below:

$c_{ijp2} = M$

$c_{ikp2} = M$

The problem is formulated as the following integer program:

$$\begin{aligned} Min \quad & \sum_{i=1}^{2}\sum_{j=1}^{n}\sum_{p=1}^{4}\sum_{t=1}^{2} c_{ijpt}x_{ijpt} \; + \\ & \sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{p=1}^{4}\sum_{t=1}^{2} c_{jkpt}x_{jkpt} \; + \\ & \sum_{i=1}^{2}\sum_{k=1}^{n}\sum_{p=1}^{4}\sum_{t=1}^{2} c_{ikpt}x_{ikpt} \; + \; \sum_{j}^{n} F_j y_j \end{aligned}$$

The objective function minimizes the total fixed and variable costs of supply chain network subject to the following constraints:

$$\sum_{j}^{n}\sum_{t}^{2} x_{ijpt} + \sum_{k}^{n}\sum_{t}^{2} x_{ikpt} \le K_{ip} \qquad \text{for i} = 1, 2 \text{ and p} = 1, 2.3, 4 \tag{1}$$

The constraint in Equation (1) specifies that the total amount of product type p. shipped from a factory cannot exceed the production source`s capacity.

$$\sum_{i}^{2}\sum_{t}^{2} x_{ijpt} - \sum_{k}^{n}\sum_{t}^{2} x_{jkpt} = 0 \qquad \text{for j} = 1, ..., \text{n and p} = 1, 2.3, 4 \tag{2}$$

The constraint in Equation (2) states that the amount shipped out of a DC cannot exceed the quantity received from the factories.

$$\sum_{k}^{n}\sum_{t}^{2} x_{jkpt} \le W_j y_j \qquad \text{for j} = 1, ..., \text{n and p} = 1, 2, 3, 4 \tag{3}$$

The constraint in equation (3) enforces that the amount shipped through a DC cannot exceed its capacity.

$$\sum_{i}^{2}\sum_{t}^{2} x_{ikpt} - \sum_{j}^{n}\sum_{t}^{2} x_{jkpt} = D_k \qquad \text{for k} = 1, ..., \text{n and p} = 1, 2.3, 4 \tag{4}$$

The constraint in equation (4) implies that the amount shipped to a customer must cover the demand.

$$y_j \in \{0, 1\},\ x_{ijpt},\ x_{ikpt},\ x_{jkpt} \ge 0 \tag{5}$$

The constraint in Equation (5) enforces that each DC is either open or closed.

The model discussed earlier allows direct shipments between factory and customer just in full track demand cases.

5. Conclusion and results

The mathematical models have been solved by a MILP solver and optimization results of proposed network obtained and illustrated as figure 2. Considering obtained results comparing with current supply network based on dealers and premiums, there is not a significant difference between costs of two supply networks.

Our model differs from those reported in the literature in two significant ways. First, we do not lump customer demand into zones but rather deal with individual customer demand. This allows the model to deal with the details of the logistical limitations related to mode of transport at each customer location. These limitations play an important role in determining permissible modes of transportation which have a significant impact on freight costs. The model is also structured to assign cost components to individual customer records. Historical records can be used to fix decision variables in the model so that a base case can be computed to validate the model and contrast it against the optimized network. The details inherent in this approach also allow the optimization results to be partitioned and prioritized for implementation.

Customer Counts	656
Verfified DC Sites Counts	29
Total DC Costs (TL/Year)	606885
Production Sites	2
Shipment Counts	720
Shipment Costs (TL)	1010226
Optimized Overall Cost	5,50E+10

Figure 2. Optimization results based on the inputs for proposed Supply network

This real-life application of supply chain network design helped us to compare our present trader based supply network which has been formed of two permanent production sources and plenty of traders whole over Turkey, with a proposed DC based supply network with 29 prospect distribution center cites.

For the future work we are going to unite different DCs and to evaluate our supply network to either open or not the new production centers using stochastic customer demands.

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Proceedings of the Global Conference on Healthcare Systems Engineering and Management 2016, Istanbul, Turkey, July 14-15, 2016

Implementation of Computer Assisted Voice Search Engine for Medical Transcription

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Abstract

An important application domain of voice recognition has emerged as health care assistance with voice-controlled systems. Development of a computer based voice recognition engine converting voice-recorded commands dictated by healthcare professionals into text format, and so providing more efficient search tool for the medical transcription systems can be performed. Health care information systems can be utilized to ease searching and analyzing datasets such as accessing to patient history just by announcing the patient's identity number, comparing the a set of past findings of a specific treatment just by telling the related disease name. Taking into account that this method is fast, cost-effective and user-friendly, the enhancement of complicated medical software programs as a dictation system would contribute significantly to clinical processes for speech transcription, indexing and voice searching, then faster analyzing of the related results. They can also be used as supporter systems by not well-trained professionals to use modern complicated medical software programs. In this study, signal processing and machine learning techniques are utilized to develop the voice controlled system. A combination of Mel Frequency Cepstral Coefficients (MFCC) and Hidden Markov Model (HMM) is used for feature extraction and classification of the words. This study demonstrates a great potential of such an voice-controlled medical software programs that could be used as a clinical tool efficiently in real life.

Keywords

Voice-controlled systems, medical transcription, signal processing, computer-aided annotation, automated healthcare systems

1. Introduction

Voice recognition research made in academia and industry for years shows that many expert systems to listen and comprehend human speech via a machine can be served. An important application domain of voice recognition has emerged as health care assistance with voice-controlled systems. Health care information systems can utilize this technology to ease searching and analyzing the all recorded data such as accessing to patient history just by announcing the patient's identity number, comparing the a set of past findings of a specific treatment just by telling the related disease name.

Voice-controlled systems can easily provide detailed information about the voiced command taken by physicians as well as contribution of its automated techniques to the real time clinical systems. Taking into account that this method is fast, cost-effective and user-friendly, the development of speaker-independent dictation system on often needed in clinical applications vocabulary data set would contribute significantly to clinical processes for speech transcription, indexing and voice searching, then faster analyzing of the related results.

A computer based voice search engine by utilizing signal processing and machine learning techniques can be developed and used in clinical systems to provide voice controlled systems, results of which can also speed up evaluation and treatment procedures. They can also be used as remote diagnosis systems in places where there may not be well-trained physicians in modern complicated medical software programs.

Related work: In last decades, speech recognition studies have been increasingly conducted to recognize about a few hundred words with different purposes such as education, medical sector, military sector and translation. The reason of this speech is the most natural way of communication with environment. Therefore, speech processing has been one of the most popular research areas of signal processing (et al., 2015). Today, automated speech recognition applications are widely needed in fields that require human machine interface. Gaikwad, et al. presented a study about discussion of all speech recognition techniques (Gaikwad, 2010). Similarly, Anusuya et al. discussed about speech recognition methods in order to provide better future content for implementation of speech recognition systems (Anusuya et al., 2009). Han et al. conducted a study by using efficient feature extraction algorithm and implementing FFT filter for enhancement with recognition rate up to 92.93% (Han et al., 2006). To extract features of speech efficiently, MFCC is a widely used feature extraction algorithm and the HMM statistical method provides the potential to recognize an unlimited number of words (Chaven et al., 2015). MFCC and HMM classifier are collaboratively used by Abushariah et al with 92% recognition rate on English digits database (Abushariah et al, 2010). MFCC and Linear Predictive coding (LPC) methods were compared by Mehta et al., and they indicated that MFCC is more successful than LPC (Mehta et al., 2013). There can be found some studies regarding automated dictation applications based on speech recognition for health care systems in the literature. Weninger et al. presented a system capable of interpreting speech commands given by a health care professional to help them by providing a natural spoken English interface (Weninger, 2009). Matheson presented a study about using an automated transcription process using digital recordings and voice recognition software (Matheson, 2007).

Our work: Technological improvements have made many aspects of data collection, management, and analysis easier and faster (Matheson, 2007). There are many researchers working on different fields who rely on technology advancements in order to reduce load of their most challenging research tasks such as managing complex software programs for clinical analysis. Advanced speech processing skills present a promising way for the development voice-controlled medical software programs. An automated dictation system would contribute significantly to clinical processes for speech transcription, indexing and voice searching, then faster analyzing of the related results. Development of a computer based voice recognition engine converting voice-recorded commands dictated by health care professionals into text format, and so providing more efficient search tool for the medical transcription systems is aimed in this study. Such a system can be implemented to use efficiently in real life. We aim to develop a computerized dictation system based on speech processing and machine learning techniques at the word based command level. They can also be used as supporter systems in places where there may not be well-trained health care professionals in modern complicated medical software programs.

The paper is organized in the following manner: Section 2 describes provides detailed information regarding the methods used in this study. Section 3 presents the experimental study carried out in the study, the evaluation procedures used and the experimental results obtained. Finally, Section 4 describes the conclusions accessed from the study.

2. Materials and Methods

2.1 Pre-processing

Pre-processing phase has an important impact on recognition performance according to information obtained from past studies (Arslan et al., 2014). The recorded data set of medical words and special commands is passed through pre-processing step that includes segmentation. In the beginning case, the raw data including voiced records and silence in length of 5 seconds. By applying segmentation, speech signal parts are detected and cropped and each of them is labeled with the appropriate information.

2.2 Feature Extraction

Feature extraction is identification of feature vectors specially owned by a sound signal. The MFCC uses the Mel scale cepstral analysis that has similar frequency response of the human ear (Ellis et al., 2005). The pseudo code of the MFCC algorithm is given in Figure 1, and then MFCC flowchart is given in Figure 2 (Gupta et al., 2013).

Algorithm 1: MFCC feature extraction algorithm pseudocode
input : signal (Phonocardiogram signal)
output : MFCC (MFCC of phonocardiogram signal)
function MFCC (parameters)
  Initialize parameters;
  Split into frames phonocardiogram signals;
  Apply **Hamming windowing** to frames;
  Get spectrum by applying **Fast fourier transform** to all frames;
  Determine matrix for a mel-spaced filterbank;
  Transform spectrum to **mel spectrum**;
  Obtain **MFCC vector** for each frame by applying **discrete cosine transform**;
end function

Figure 1: Pseudo code of the MFCC algorithm used in the study

Frame blocking is the first step of MFCC in which speech signals are separated into short time intervals and each of them are framed (Schafer et al., 1975). The values of frame length and shifting value can be defined according to results of experimental study and improved. In the literature, frame length is suggested between 20 and 30 ms (Arslan et al., 2014; Vyas et al., 2013; Verma et al., 2014).

The second step of MFCC is windowing that is implemented to reduce discontinuities placed at the beginning and end points of the each frame. One of the widely used windowing functions is Hamming windowing function that is applied to the input signal as follows:

$$Y(m) = X(m)\, W_n(m), \quad 0 \leq m \leq N_m\text{-}1 \qquad \text{(1) (Gupta et al., 2013)}$$

X(m) defines input signal, *Y(m)* defines the output signal, $W_n(m)$ represents the hamming window implemented to the *X(m)*, N_m is the number of samples within each window in Equation 1. $W_n(m)$, the Hamming function is given in Equation 2:

$$W_n(m) = 0.54 - 0.46 \cos\left(2\pi m / (N_m - 1)\right), \quad 0 \leq m \leq N_m\text{-}1 \qquad \text{(2) (Gupta et al., 2013)}$$

Fast Fourier Transform (FFT) is implemented to convert the samples from time domain to frequency domain. FFT implementation on N_m samples is shown in Equation 3:

$$D_m = \sum_{m=0}^{N_m-1} \left(e^{-\frac{j2\pi km}{N_m}} D_k\right) \quad k = 0,1,2,\ldots, N_m\text{ -1} \qquad \text{(3) (Gupta et al., 2013)}$$

D_k is the frame, D_m is the calculated complex numbers. Equation 4 is performed to transform the frequency into mel-frequency where *f* is frequency in hertz, *M* is the mel frequency:

$$M = 2595 \log\,(1 + f/700) \qquad \text{(4) (Gupta et al., 2013)}$$

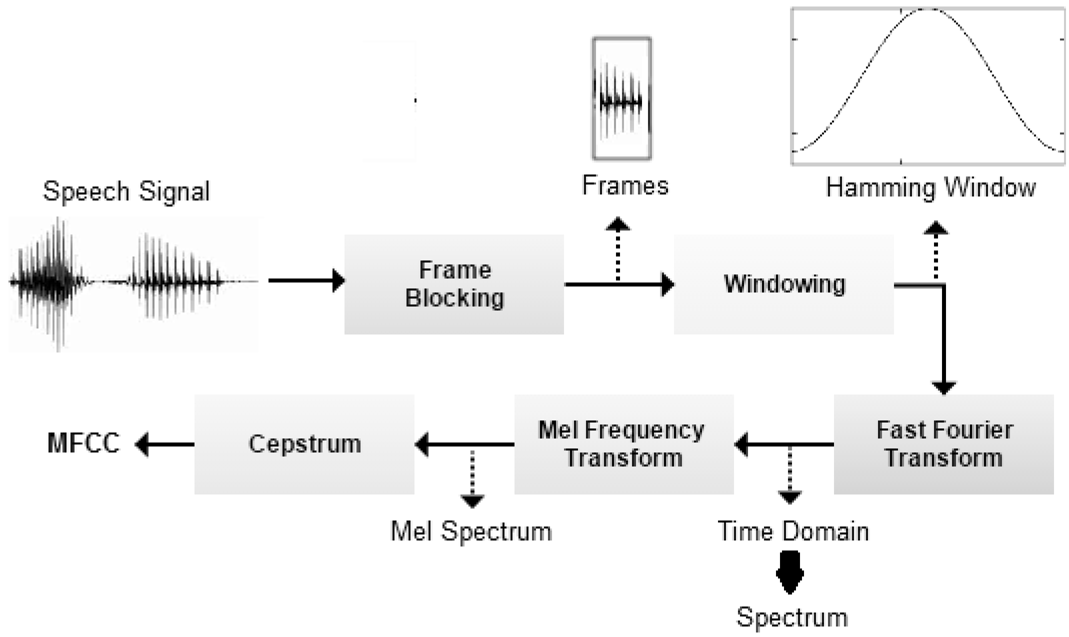

Figure 2: The flow procedure of the MFCC feature extraction used in the study

As the last process, workspace is converted from frequency domain to time domain by applying inverse Fourier transformation on all frames. As a result of this operation *MFCC* values are extracted as shown in Equation 5:

$$\mathrm{MFCC} = \sum_{k=1}^{k} (\log D_k) \cos[m(k-1/2)\,\pi/k\,] \qquad m=0,1,\ldots,k-1, \qquad (5)\text{(Gupta et al., 2013)}$$

m represents the number of coefficients, ($\log D_k$) represents the log-energy output of the k_{th} filter. *MFCC* feature vectors of each frame are extracted in defined *MFCC* size.

2.3 Classification

HMM is a widely known statistical classification algorithm determining based on the probability weights adjusted by a probability distribution of states and transitions (Schafer et al.,1975). After applying HMM, firstly unknown HMM parameters are obtained by implementing the Baum-Welch algorithm on extracted MFCC feature vectors and maximum likelihood parameter estimation. This improves the classification performance due to using feature vector in reduced size rather than using the entire feature vector.

$q_t = S_i$ shows that a system is in S_i case at t time, and this system is always in one of N different states ($S_1, S_2, .., S_N$).

$P(q_t=S_j \mid q_{t-1}=S_i,\, q_{t-2}=S_k,\, \ldots)$ is the probability from a state to another state, this expression is dependent on the previous state.

$$P(q_{t+1}=S_j|q_t=S_i,q_{t-1}=S_k,\ldots)=P(q_{t+1}=S_j|q_t=S_i) \qquad (6)$$

In Equation 6, a state at time $t + 1$ is dependent on the state at time t according to the first-degree Markov model (Arslan et al., 2014).

N is the number of states in the HMM; $S=\{S_1,..S_N\}$, *M* is the number of observations; $V=\{v_1, \ldots v_M\}$, *A*, state transition probability matrix is seen in Equation 7:

$$A=[a_{ij}],a_{ij}=P(q_{t+1}=S_j,|q_t=S_i) \qquad (7)$$

B is observation probability matrix that is seen in Equation 8:

$$B=[b_j(m)],\ b_j(m)=P(O_t=v_m|q_t=S_j) \qquad (8)$$

π, the initial state probabilities vector that is seen in Equation 9:

$$\pi=[\ \pi_i],\ \pi_i=P(q_t=S_i) \qquad (9)$$

After *N* and *M* system parameters are determined, $\lambda = (A, B, \pi)$ statement creates HMM.

3. Experimental Study

3.1 Training

An automated voice recognition and search engine was implemented in this study with the aim of medical usage in clinics. The flowchart of the developed system to recognize speech signals is given in Figure 3.

The used data set firstly needs segmentation that was implemented in the pre-processing step. Manual segmentation and labeling processes were implemented on each data. In feature extraction step, the feature vector of each speech data was extracted by using MFCC algorithm. 22.050 Hz signals were framed in 25 ms length, the shifting value was selected as 1/3 ~ 1/2 of the frame size. Hamming windowing function is applied on each frame by multiplying. Then, FFT was applied on these frames for transformation from the time domain into the frequency domain. The mel scale response of the spectrum was calculated. By applying the discrete cosine transform obtained mel spectrum is transformed to the time domain. The number of extracted coefficients from each frame in MFCC algorithm was determined as 22.

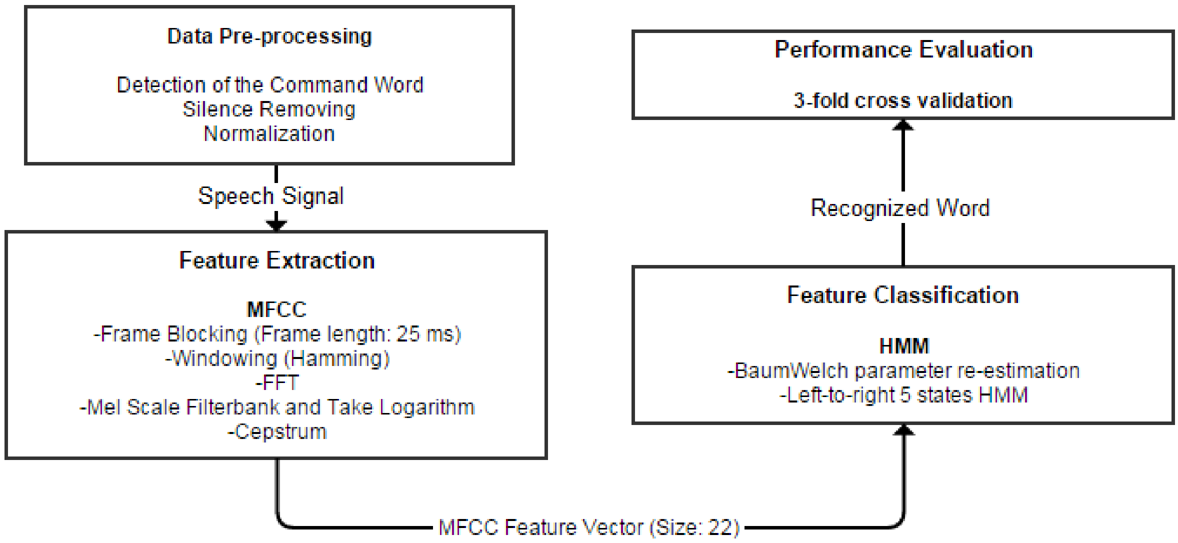

Figure 3: The flowchart of the voice search engine study to recognize speech signals

Principal parameters of HMM classifier were defined by applying Baum Welch algorithm on the extracted features. In this way, unknown HMM parameters were determined both more accurately. At the same time, compact parameters were stored instead of all feature vectors thanks to Baum Welch algorithm that increases the classification performance by working on reduced vectors.

Different situations of a speech segment from beginning to end point form states of HMM state machine, and the number of states was defined as "5" in this study (Figure 4). In classification left to right HMM classifier was formed, by assigning probabilities to the transitions between sequential segments appropriately in order to train system.

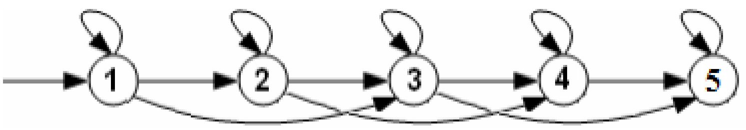

Figure 4: 5-states Hidden Markov Model.

3.2 Testing and Validation

Test and validation of the developed system were conducted by k-fold cross validation technique. In 3-fold cross validation, 3 subsets of dataset that has nearly 100 data, so 2/3 of dataset was used for training, the remaining samples were used for testing. The classification process was repeated for 3 times so that each subset was used in testing and the others were used in training. As an important point, there has been no change in performance when the 3-fold and 5-fold cross validation is applied. It is seen that the feature vector size representing speech signals has an important effect on classification performance. Thus, the obtained performances in different vector sizes, frame length, shifting value and k value in k-fold cross validation were analyzed and the best values were used.

4. Conclusions

In traditionally clinical applications, if a health care professional wants to search for a past or present patient, or about information of a disease the professional must either manually enter patient identification data into a computer program or directly on the paper records. While reviewing a current case the health care professional wants to look at past samples of the same complaint, or get information about symptoms, etc. then the professional needs to manually enter each symptom name and all of the appropriate search terms manually over software programs. Development an automated voice recognition and search engine even using limited keywords the load of health care professional can be significantly reduced and searching, analyzing and reporting tasks can be facilitated. Therefore, we conducted a study that is an Turkish-based, medically oriented voice-directed search engine. This system would be more practical and easier to use in clinical applications. When recognition performance is analyzed, Lin's Concordance Correlation Coefficients (CCC) is obtained as 0.921, 95% confidence interval. This study demonstrates a great potential of such an voice-controlled medical software programs that could be used as fast and cost-effective clinical tool efficiently in real life.

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Prioritized scheduling and routing for home healthcare services

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We present a comprehensive methodology for solving a real-world home healthcare scheduling and routing problem from a Turkish healthcare company. Each nurse is assigned to a number of patients to visit either at their homes or call by phones to check their conditions. Each patient has a certain time interval in which they prefer to have service. When a patient is visited by a nurse, there is an associated service to the patient. The nurse wants to determine her daily schedule by considering patient priorities and distances between patients and decide on which patients to visit each day in what order. Patient priority depends on several factors such as the last visit time, severity of his/her condition, etc. One important aspect of the priority parameter is that it is updated by time. As time progresses, the priority of an unvisited patient increases. We developed a mixed integer programming model to solve the scheduling and routing problem of the nurse's daily visits. The model simultaneously determines which patients to visit and in which order to visit the patients.

Acknowledgements

We thank Nutricia for providing data and expertise.

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Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Role of Entrepreneur Orientation on Employee Work Outcomes

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Abstract

In today's business environment, organizations should be capable of adapting to the changing business dynamics. During adaptation processes, innovation and entrepreneurship activities are considered to be vital both for survival and competitive advantage of companies. Accordingly, entrepreneurial orientation; i.e., intrapreneurship, becomes a prominent capability for organizational sustainability. Organizational culture is an important concept that supports organizational goals and strategies and thus it has been an important aspect of organizational competitiveness. For the efficient implementation of business strategies, organizational culture should be evaluated and cultivated in connection with organizational circumstances. In this regard, type of organizational culture is important for promoting innovation and entrepreneurship activities of organizations. The effects of entrepreneurial orientation are not limited to organizational level outcomes, such as financial performance; but it may also influence employee work outcomes. This study aims to explore the organizational culture attributes effective on entrepreneurial orientation of organizations, which is expected to be influential on employee job satisfaction. The data was collected from 289 employees of the six fast moving consumer goods (FMCG) companies in Turkey with dominant market shares. Hypothesized relationships were tested by multiple regression analyses.

Keywords

Entrepreneur orientation, intrapreneurship, organizational culture, job satisfaction

1. Introduction

Today's business environment necessitates organizations and industries to be capable of adapting to rapid change and innovation in order to survive within fierce competitive landscape. Correspondingly, overwhelming technological developments dramatically reform business processes and product designs. These environmental necessities force companies to involve in creative and innovative behaviors both within and outside organizations. While entrepreneurship as a concept indicates developing a new venture outside an existing organization, intrapreneurship, i.e., entrepreneur orientation, involves practices of innovation within an existing organization to exploit a new opportunity and create value (Antoncic and Hisrich, 2001). The value creation through entrepreneur activity within organization comes mainly from renewing and revitalizing the existing business processes and products; and so enhancing overall organizational performance and competitive position of an established organization (Zahra, 1991; Parker, 2011). While most of the studies in the extant literature focus on the financial outcomes of intrapreneurship, very few studies try to explore its effect on employee attitudes and behaviors. In fact, by the increased importance of know-how along with the scarcity of the talented employees having that professional knowledge, human capital has become one of the most important assets of today's businesses. Therefore, understanding the effects of organizations' entrepreneurial orientation on employee outcomes sets as an area that need further investigation. Organizational culture is an important concept that mainly designates the internal dynamics of organizations. Organizational culture does not only affect employee outcomes, but also support organizational goals and strategies; for that reason it has been an important aspect of organizational competitiveness. For the efficient implementation of business strategies, organizational culture should be evaluated and cultivated in connection with organizational circumstances. In this regard, organizational culture characteristics are important for promoting innovation and entrepreneurship activities of organizations. Based on "Competing Values Framework" developed by Cameron and Quinn (1999), this study aims to explore the effects of organizational culture type on organization's entrepreneurial orientation, which is expected to be effective on employee work outcomes, specifically job satisfaction.

2. Theoretical Background and Hypotheses

2.1. Entrepreneur Orientation

In the extant literature, there are different terminologies used for defining entrepreneur efforts within organizations; such as intrapreneurship, corporate entrepreneurship, corporate venturing and firm-level entrepreneurial orientation. The common element that unities these different terminologies is the fact that they all focus on entrepreneur activities within the context of an established organization. Among different conceptualizations of entrepreneur orientation, the one by Lumpkin and Dess (1996) stands out by being highly referred in academic studies. Lumpkin and Dess (1996) defined entrepreneur orientation through five dimensions; which are; autonomy, innovativeness, risk taking, proactiveness, and competitive aggressiveness (p.152). The definition of each of the five dimensions are as follows:

Autonomy describes the authority and independence given to entrepreneurial leaders or teams within the firm to develop business concepts and visions and carry them for completion.

Innovativeness is the predisposition to engage in creativity and experimentation through the introduction of new products/services as well as technological leadership via R&D in new processes.

Risk-taking reflects an acceptance of uncertainty and taking bold actions, typically characterized by resource commitment to uncertain outcomes and activities.

Proactiveness is an opportunity-seeking, forward-looking perspective characterized by the introduction of new products and services ahead of the competition and acting in anticipation of future demand.

Competitive aggressiveness is the intensity of a firm’s effort to outperform rivals and is characterized by a strong offensive posture or aggressive responses to competitive threats.

2.2. Organizational Culture

Organizational culture, which is defined as "*the learned pattern of basic assumptions of organizational members formed while they solved their external adaptation and internal integration problems",* sets implicit constraints and internally adopted rules while conducting organizational processes (Schein, 1992, p.12).

The Competing Values Framework presents a taxonomy of cultural values through two dimensions; *organizational focus* with internal vs. external orientation, and *organizational control* with flexibility/discretion vs. stability/control (Cameron and Quinn, 1999). The Competing Values Framework can be used in constructing an organizational culture profile based on four dominant culture types (i.e., clan, adhocracy, market, and hierarchy) by using the "Organizational Culture Assessment Instrument (OCAI)" developed by Cameron and Quinn (1999). Through the use of the OCAI, overall culture profile of an organization can be identified as one of the following four culture types:

Clan type organizational culture concentrates on internal maintenance with concern for people, and depend on shared values to hold the organization together.

Hierarchy type organizational culture concerns for stability, predictability, efficiency, and depend on formal rules and policies to hold the organization together.

Adhocracy type organizational culture concentrates on quick adaption to new opportunities by fostering adaptability, flexibility and creativity.

Market type organizational culture has an external focus by concentrating on competitiveness and productivity.

Based on previous research findings, organizational culture characteristics and intraprenurship activities are expected to be associated, such that while some cultural variables foster entrepreneurial activities some may restrain them (Covin and Slevin, 1991; Zahra, 1991). In line with previous research, within the context of the current study the following hypothesis are proposed:

H1: There is a positive relationship between *clan* type organizational culture and entrepreneur orientation.

- H1.a: There is a positive relationship between clan type organizational culture and innovativeness.
- H1.b: There is a positive relationship between clan type organizational culture and risk-taking.
- H1.c: There is a positive relationship between clan type organizational culture and proactiveness.
- H1.d: There is a positive relationship between clan type organizational culture and competitive aggressiveness.
- H1.e: There is a positive relationship between clan type organizational culture and autonomy.

H2: There is a positive relationship between *hierarchy* type organizational culture and entrepreneur orientation.

- H2.a: There is a positive relationship between hierarchy type organizational culture and innovativeness.
- H2.b: There is a positive relationship between hierarchy type organizational culture and risk-taking.
- H2.c: There is a positive relationship between hierarchy type organizational culture and proactiveness.
- H2.d: There is a positive relationship between hierarchy type organizational culture and competitive aggressiveness.
- H2.e: There is a positive relationship between hierarch type organizational culture and autonomy.

H3: There is a positive relationship between *adhocracy* type organizational culture and entrepreneur orientation.

- H3.a: There is a positive relationship between adhocracy type organizational culture and innovativeness.
- H3.b: There is a positive relationship between adhocracy type organizational culture and risk-taking.
- H3.c: There is a positive relationship between adhocracy type organizational culture and proactiveness.
- H3.d: There is a positive relationship between adhocracy type organizational culture and competitive aggressiveness.
- H3.e: There is a positive relationship between adhocracy type organizational culture and autonomy.

H4: There is a positive relationship between *market* type organizational culture and entrepreneur orientation.

- H4.a: There is a positive relationship between market type organizational culture and innovativeness.
- H4.b: There is a positive relationship between market type organizational culture and risk-taking.
- H4.c: There is a positive relationship between market type organizational culture and proactiveness.
- H4.d: There is a positive relationship between market type organizational culture and competitive aggressiveness.
- H4.e: There is a positive relationship between market type organizational culture and autonomy.

2.3. Entrepreneur Orientation and Employee Outcomes

While most of the studies in the extant literature focus on the financial outcomes of intrapreneurship, very few studies try to explore its effect on employee attitudes and behaviors. In fact, with the increased importance of know-how and business talent, for today's organizations human capital has become one of the most important assets. The empirical study of Antoncic and Antoncic (2011) is among the few studies that investigated the presence of an association between intrapreneurship and employee job satisfaction. The results of their study indicates a positive association between these two constructs. Accordingly, understanding the effects of organizations' entrepreneurial orientation on employee outcomes sets as an area that need further investigation. Building on the findings of previous research we propose the following hypothesis within the context of the current study:

H5: Entrepreneur orientation is positively associated with employee job satisfaction

3. Method

3.1. Sample and Procedure

The data were collected from 289 employees working in the six fast moving consumer goods (FMCG) companies with dominant market shares in Turkey. Prior to administering the questionnaire, the items in the questionnaire were tested and refined through a pilot study. The data were collected on-site by the researchers during normal business hours. Before handing out the questionnaires, the researchers gave instructions to the participants regarding how to fill in the questions, while ensuring anonymity.

3.2. Measures

The measures of interest were taken from the established scales in western countries. For Turkish versions, “back translation” procedure (Brislin, 1980) was used to assure the equivalence of these measures in English and Turkish. For the measurement of constructs, 5-point Likert scale (1 = strongly disagree; 5 = strongly agree) was used. The measures to which respondents responded are as follows.

Entrepreneur orientation: The work of Lumpkin and Dess (1996) was used as a reference in developing scales for the dimensions of entrepreneur orientation. The five dimensions of entrepreneur orientation; i.e., autonomy, innovativeness, risk taking, proactiveness, and competitive aggressiveness were measured by 18 items in total.

Organizational culture types: Clan, adhocracy, hierarchy, and market culture types were measured by the Organizational Culture Assessment Instrument (OCAI) based on the Competing Values Framework (Cameron and Quinn, 1999). We chose the Competing Values Framework due to its applicability and capability to measure organizational culture profiles systematically. Each of the organizational type was depicted through the analysis of four key dimensions of each culture, i.e., dominant characteristics, organizational glue, strategic emphases, and criteria for success (Cameron and Quinn, 1999). Accordingly, in total 16 items were used for measuring organizational culture types.

Job satisfaction is measured with a five item scale developed by Judge, Locke, Durham, & Kluger (1998).

4. Analysis and Results

As a first step, an exploratory factor analysis (EFA) was conducted with the principal component extraction and varimax rotation method. During EFA analysis, the scale items which have less than 0.50 corrected item-total correlations and/or do not substantially contribute to the coefficient alpha of the construct were deleted (Netemeyer et al., 2003).

As a result of the EFA analyses, the sub-dimensions of entrepreneur orientation grouped under three separate factors rather than five as supposed to the previous conceptualization by Lumpkin and Dess (1996). According to the factor analysis, the items of risk-taking and autonomy were loaded to the same factor. Due to their scope and theme, these compound items of risk-taking and autonomy are named as *"Initiative Opportunities"* within the context of the current study. Similarly, the items of innovativeness and proactiveness were also loaded to a single factor. In regard to the content they measure, the compound items of innovativeness and proactiveness are named under *"Proactive Innovativeness"* within the context of the current study. Lastly, the items of competitive aggressiveness were loaded to a single item, and named originally as *"Competitive Aggressiveness"*. The factor analyses results confirmed the item distribution of four organizational culture profiles, (i.e., clan, adhocracy, market, and hierarchy), in line with OCAI based on the Competing Values Framework (Cameron and Quinn, 1999). Finally, the job satisfaction items were loaded to a single factor as expected.

As a next step, the reliability of each scale is examined by computing the Cronbach's alpha coefficients of each factor obtained from the EFA analysis. For ensuring high internal consistency, Cronbach's alpha of a scale is expected to be around 0.70; however in exploratory research Cronbach's alpha values around 0.60 also accepted as a legitimate internal consistency level (Hair et al., 2010). The Cronbach's alpha values of each scale of the study indicated an adequate internal consistency; with the reliability values of initiative opportunities (α=0.892), proactive innovativeness (α=0.753), competitive aggressiveness (α=0.729), clan culture (α=0.773), adhocracy culture (α=0.716), market culture (α=0.678), hierarchy culture (α=0.833), and job satisfaction (α=0.834) respectively.

After factor analyses were successfully conducted, multiple linear regression analyses were applied in order to test the hypotheses of the study. First group of regression analyses were conducted for analyzing the association between organizational culture types and dimensions of entrepreneurship orientation. The subsequent regression analyses were aimed for exploring the possible indirect effect of organizational culture type on employee job satisfaction through entrepreneurship orientation.

Regression analyses were conducted with forward stepwise method designed to select from a group of independent variables the one with the largest semi-partial r-squared at each stage, therefore making the largest contribution to R-squared, explicitly having the highest association with the dependent variable.

First regression analysis was conducted for identifying the organizational culture type which mostly facilitates risk-taking and autonomy orientation, i.e., *initiative opportunities.* The results indicate that Adhocracy (β = 0.45, $p < 0.01$), Hierarchy (β = 0.37, $p < 0.01$), and Clan (β = 0.17, $p < 0.01$) culture types have a positive and significant direct effect on *initiative opportunities*.

Next analysis was conducted for identifying the organizational culture type which mostly facilitates innovativeness and proactiveness, i.e., *proactive innovativeness.* The results indicate that Adhocracy (β = 0.50, $p < 0.01$), Hierarchy (β = 0.30, $p < 0.01$), and Clan (β = 0.20, $p < 0.01$) culture types have a positive and significant direct effect on *proactive innovativeness*.

Afterwards, another regression analysis was conducted for identifying the organizational culture type which facilitates *competitive aggressiveness.* The results indicate that Hierarchy (β = 0.34, $p < 0.01$), Clan (β = 0.31, $p < 0.01$), Market (β = 0.18, $p < 0.01$), and Adhocracy (β = 0.15, $p < 0.01$) culture types have a positive and significant direct effect on *competitive aggressiveness*.

These results indicate that while Adhocracy, Hierarchy and Clan type organizational cultures facilitate all dimensions of entrepreneur orientation; Market type organizational culture only facilitates competitive aggressiveness aspect of entrepreneur orientation. Therefore, while H1, H2, and H3 of the study are fully supported; H4 is partially supported.

In order to test H5 of the study, a regression analysis was conducted in order to identify the dimensions of entrepreneur orientation which significantly affect employee job satisfaction. The results showed that while initiative opportunities ($\beta = 0.55$, $p < 0.01$), and proactive innovativeness ($\beta = 0.40$, $p < 0.01$) are found to be influential on employee job satisfaction; the third dimension of entrepreneur orientation, that is, competitive aggressiveness does not have a significant effect on employee job satisfaction. Therefore, H5 is partially supported.

5. Discussion and Conclusion

The results of the study show that organizational culture types have significant impact on entrepreneur orientation of companies, which in turn affect employee job satisfaction. Among four different organizational culture types, adhocracy type organizational culture, which is characterized by the willingness to take risks, utilization of pioneering strategies in creativity and innovation, is found to be the most influential cultural orientation that facilitate entrepreneur orientation within organizations.

The findings of the current study point that different aspects of entrepreneur posture can be nourished by different organizational aspects; specifically, different cultural structures may facilitate different facets of intraprenurship within organizations. Specific cultural norms promotes innovation and entrepreneurship activities of organizations.

Moreover, organizational culture is an important element of organizations that support organizational competitiveness. For the efficient implementation of business strategies, organizational culture should be cultivated in connection with organizational circumstances. In this regard, organizational leaders may consider to target transformation of their organizational cultures if there are discrepancies between current and preferred cultural norms that would support their competitive strategies.

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Biography

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A System Dynamics Model of Medication Waste Problems in the Saudi Arabian Healthcare System

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Abstract

The components of the modern Saudi healthcare system (SHCS) and its historical development are studied and briefly discussed. The nearly 80 years old system is found to have made considerable advancements. However, our findings strongly suggest that there are still opportunities for significant improvements in certain areas to further elevate the system and produce better health value. One of the most serious issues is medication waste in Saudi households of individuals 20 years of age and older. This is a costly problem existing in virtually every corner of the system. The present work attempts to contribute to improving this burden on the system. Although related problems have been reported for modern healthcare systems worldwide, our work focuses heavily on certain aspects of the SHCS including: 1) government subsidies to support the provision of medications, and 2) allowing the buying/acquiring of medicines without a formal prescription. To this end, the main goals of the present work are twofold: 1) study the dynamic causes contributing to such issues, and 2) identify points of intervention, based on which certain policies and changes are proposed to improve the situation. In addition, we perform a comparative study of the SHCS and United States healthcare system (USHCS) with reference to the issues under consideration, and discuss implications for the USHCS based on both the nature of the USHCS and the findings of this study. System thinking techniques are used to develop the system model, including reference mode and system dynamics modeling tools.

Keywords

Saudi Healthcare System, Medication Waste, Policy Interventions

1. Introduction

Saudi Arabia (the 13th largest country in the world by area) is divided into 13 provinces, with a total population of 30.77 million. 68% of the total population are Saudi citizens, with 50.2% male and 49.8% female (*Central Department of Statistics and Information, Saudi Government* [CDSISA], 2014). The Saudi population is very young, with around 37.2% under 15 years of age, 67.1% age 30 or below, and an estimated 5.2% greater than 60 (CDSISA, 2014).

Prior to the establishment of the modern Kingdom of Saudi Arabia in 1932, local healers usually provided rudimentary care for their communities. However, in the past several decades, the Saudi government has been successful in establishing a modern healthcare system, ranging from primary healthcare community centers to world-class highly specialized care. The challenge of the future is in meeting the demand for healthcare services that continues to be fed by an expanding population with an increasing average income (Colliers International, 2012).

2. Overview, Basic Components and Assessment of the Saudi Healthcare System

The transformation of the SHCS really began to take off in 1970, after the country became a major producer and exporter of oil (Almalki et al., 2011). At that point, it had been 20 years since the establishment of the **Ministry of Health** (MOH), and there were 74 hospitals (9,039 beds) in the kingdom. Today the MOH has a total of 268 hospitals (38,970 beds), and 2,037 primary healthcare centers (PHCs). The MOH is the major provider and financer of healthcare services in the country, providing 60% of total health services (Almalki et al., 2011; *Ministry of Health* [MOH], 2016). As the single point of control in the system, the MOH is responsible for developing health policies, planning and supervising health programs, and monitoring health services in the country including the private sector. It is also responsible for advising other governmental agencies and the private sector on ways to achieve the government's healthcare objectives. Other **governmental bodies** and

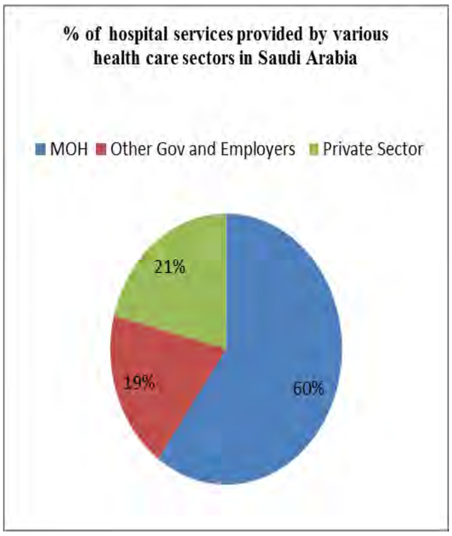
quasi-governmental employers account for 19% of the healthcare services provided in the country, with the remaining 21% provided by the **private sector** (Almalki et al., 2011). The relative shares of the hospital services are shown in Figure 1. Although the government provides free public health services to all citizens and expatriates working in the public sector (Almalki et al., 2011), a considerable number of Saudi residents choose private sector dispensaries, clinics and hospitals for their primary care visits and specialized care. These **self-funded individuals** are expected to pay the healthcare facility directly at the time of service (Al-Ghanim, 2004). Basic functional components of the SHCS — financing, payment, and delivery — are shown in Figure 2. Care is provided within the delivery domain.

The Saudi government has recognized the importance of including health **insurance** (shown in the payment domain, Figure 2) in the system to facilitate a real system transformation, so that the system will be able to meet the growing demand for healthcare services. The Council for Cooperative Health Insurance was established in 1999 (Almalki et al., 2011), and soon developed a three-stage plan to incorporate health insurance in the SHCS. Only the first-stage policies have been developed and implemented to date (more details can be found in Almalki et al., 2011 and Colliers International, 2012).

2.1 Assessment of the Saudi Healthcare System

The Saudi government began with a focus on healthcare convenience and accessibility, and created the necessary infrastructure (hospitals, clinics, pharmacies, laboratories, etc.). Once these facilities were established to cover the population needs of the 13 provinces (MOH, 2016), quality of care became the concern. Between 2005 and 2008, Saudi Arabia allocated approximately SR 23.5 billion per year (US$1=SR 3.75), for a total investment in the healthcare sector of SR 94 billion (Colliers International, 2012). The budget allocation has been aggressively increasing each year, it reached SR 113 billion in 2012 and 2013 (Colliers International, 2012). However, in terms of relative spending on healthcare as a percentage of GDP, Saudi Arabia is still behind developed nations such as the USA, Japan and Germany (Colliers International, 2012).

In order to meet the health services needs of all residents, from preventive care through advanced surgery, the MOH has implemented a two-tier strategy to make efficient use of their network of healthcare facilities. The first tier, represented by a network of PHCs throughout the country, has succeeded in improving health standards in the nation (RESA, 2016). The first tier services are backed by the second tier: a network of hospitals and specialized treatment facilities accessible to all, located mainly in major urban areas. The SHCS has a number of specialized hospitals and convalescent facilities that provide quality care over a wide range of health services, including gynecology and obstetrics, psychiatric care, respiratory ailments, eye disorders and contagious diseases.



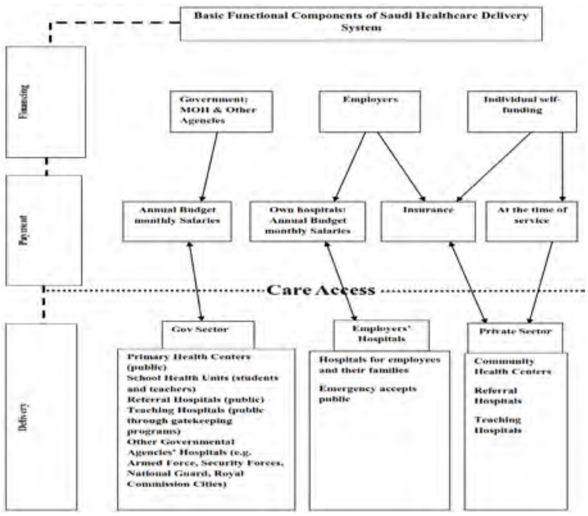


Figure 1: Hospital services by various sectors. Figure 2: Basic components of the Saudi healthcare system.

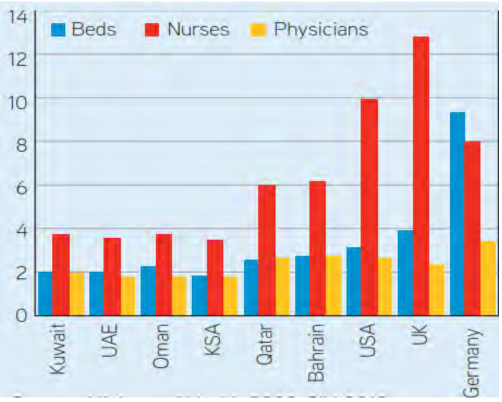
Sophisticated surgical procedures, including open heart surgery and highly specialized cardiac care, are also performed in the country (RESA, 2016). However, like the PHCs and clinics, the secondary and tertiary care facilities have also experienced a rapid increase in demand. The growth of public healthcare facilities is not keeping pace with population growth, especially at the tertiary care level, and long waiting periods at public hospitals, bed shortages, and an increasing rate of chronic disease are major issues affecting quality of care (Barrage et al., 2007). Furthermore, the concentration of highly specialized hospitals in major cities, far from where many patients live, has made it difficult to achieve equity in health care. The government has recognized the need to eliminate such disparities and improve health services for all, and has initiated a program called "my-referral," which offers patients free round-trip flights to specialized hospitals for appropriate treatment (Barrage et al., 2007). The my-referral program covers all 13 provinces, prioritizing patients based on their medical condition. This is considered a mid-term solution. The long-term solution currently under development has established five new major medical cities, offering all the required specialties in locations closer to many patients. This long-term plan will significantly expand the capacity of the system in terms of number of beds. However, it is likely to worsen the already existing manpower problem. The current situation is illustrated in Figure 3, which compares Saudi Arabia (KSA) to a number of developed countries and other countries in the region by the number of beds, nurses, and doctors per population. The figure demonstrates that there is currently a shortage in Saudi Arabia, which has even lower numbers than the other countries in the region (Colliers International, 2012).

Excessive waiting times have been identified as one of the factors causing underutilization of public health services and limiting accessibility (Al-Ghanim, 2004). Al-Ghanim (2004) reports that individuals in Saudi Arabia make a substantial number of visits to private hospitals and outpatient clinics, paying out of pocket at the time of service, instead of visiting free public hospitals and PHCs. It is estimated that residents of Saudi Arabia visit healthcare facilities an average of five times per year and that 31% of such visits are to private sector facilities (Colliers International, 2012). Along the same lines, the MOH recently announced that it has spent SR 1.8 billion on the treatment of patients in private hospitals; more details are in (Rasooldeen, 2013). Another indicator that is useful in assessing the SHCS is life expectancy, which has been increasing since the establishment of the modern SHCS (World Bank, 2014a; World Health Organization, 2015). Saudi Arabia has a life expectancy of approximately 75 years, which is lower than in developed nations, such as the USA and the United Kingdom, but better compared with other countries in the region, Figure 4.

2.2 Areas of Improvement in the Saudi Healthcare System

The SHCS has clearly come a long way. Public and private PHCs and hospitals have been established throughout the country. Highly sophisticated procedures and specialized hospital services have been available in urban areas for decades. In addition, there are a number of well-staffed and well-equipped research centers. The SHCS seems to be on track for continued, rapid advancements, by measures of both quantity and quality.

Based on the discussion so far, however, it appears that there is still a need for significant work in three main areas: 1) facility planning and expansion, 2) development and training of a sufficient number of healthcare workers (human resources), and 3) policy development and implementation.



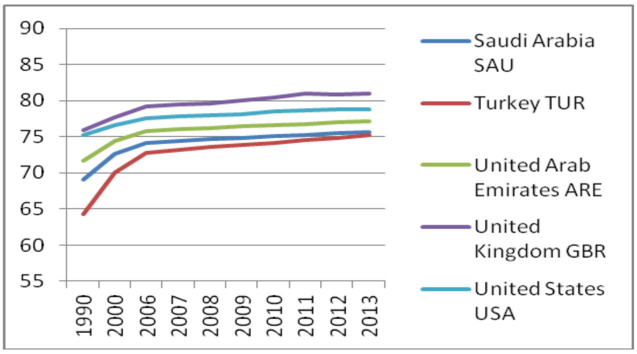


Figure 3: KSA & International Comparative analysis / 1,000 Persons (Colliers International, 2012).

Figure 4: Total life expectancy at birth in years.

If successfully approached, these three major areas of improvement should bring advances in efficiency, performance, safety and ultimately outcomes. The remainder of this study will concentrate on tackling an issue in policy development (area 3 above). In this work, we address medication waste in Saudi households consisting of individuals 20 years of age and older. In the following sections, we discuss: the degree of waste, the dynamic causes contributing to the problem, points of intervention to improve the situation, and other related aspects.

3. Medication Waste in the Kingdom of Saudi Arabia

3.1 Introduction

The problem of medication waste is an issue in healthcare systems worldwide (Al-Dhawailie, 2010). Medication waste is defined in (Abou-Auda, 2003; Celik et al., 2013) as "any drug product, either dispensed by a prescription or purchased over-the-counter that is never fully consumed." Despite the potential harm and negative impact of medication waste on patient safety, environmental safety and healthcare expenditures, the problem of reducing the amount of medication waste has received scant attention in the literature. The research presented in this paper attempts to fill gaps between the established research on medication waste and the problem of implementing policies to improve the situation.

The literature reveals that the level of medication waste in the SHCS is very high and particularly problematic in: 1) households, and 2) in-patient settings (Abou-Auda, 2003; Al-Dhawailie, 2010). Al-Dhawailie (2010) reports that although medication waste occurs every day in most local hospitals, it does not receive sufficient attention from hospital pharmacists or management. On the other hand, the literature shows great concern regarding the amount of waste in households (Abou-Auda, 2003; Al-Dhawailie, 2010; Celik et al., 2013), and this is the focus of our study. It is relevant to mention that a large percentage of total healthcare cost is related to expenditures on prescription and over-the-counter medications (Celik et al., 2013). It is emphasized in (Abou-Auda, 2003) that the successful control of such large costs requires collective and collaborative efforts involving governments, healthcare providers and consumers. This integrated approach should reduce the unnecessary burden on an already financially strapped healthcare system, without adversely affecting quality of care.

An estimation of the degree, type and cost of medication waste in Saudi households is attempted by (Abou-Auda, 2003). The study reports that approximately 81.8% of households were found to have 5 or more medicines at home, and 29.9% had at least 10. Less than 0.5% reported having no medicines. The average family consisted of 7 members (this is quite close to the average Saudi family size, 6.4 members). The average number of medicines per individual was 1.53. The average cost of expired/unusable medicines per individual was US $1.90. The average medication waste was estimated to be 25.8% of medicines available at the house. The total value of medication waste was estimated in 2002/2003 to be approximately US $150 million annually for Saudi Arabia (population around 21 million at the time) and 5 of the Gulf countries (population around 7 million at the time). Using the data in the study, we estimated the cost of medication waste in Saudi Arabia alone to be around $100 million (±15%).

3.2 Analysis of Dynamic Factors Contributing to Waste of Medicine, and Reference Mode Development

The "reference mode" in a system dynamics model refers to a set of curves in a graph(s), associated with key descriptive variables that characterize a problem dynamically (Sterman, 2000). This is helpful in not only formulating the dynamic hypothesis (how the problem arises) and mapping causal structure, but also during the model validation and testing process. In other words, by comparing model results to the reference mode, we can check whether the model is able to reproduce the problem behavior adequately for our purposes. Our reference mode (Figure 5) shows how the key variables may behave over a specific time horizon, thus describing the problem development graphically. In this section, we continue our discussion of the key variables and concepts of the model, as we discuss the reference mode and dynamic factors contributing to the problem. Note that a clause written in *italics* is either a variable or a parameter and shows up explicitly in the model.

Going back to the problem discussion, a medication can be said to be "rationally used" when it is being used by a patient for an adequate length of time, is clinically appropriate for the patient's medical needs, is taken as prescribed, and with a treatment response assessed by a qualified health professional. "Irrational prescribing," on the other hand, refers to the use of an incorrect drug for a specific condition requiring drug therapy, the use of drugs with unproven effectiveness, the use of drugs of uncertain safety status, or the use of a correct drug with an incorrect administration, dosage or duration (Celik, et al., 2013).

In their literature review, (Celik et al., 2013) reported that an estimated 37% of Saudi households indicated that they never checked the expiration date of a medication prior to administration. It further states that self-medication was common practice among households, with a mean of 20.6% of Saudi households reporting that family members took drugs prescribed for their friends or other family members, and 43.9% purchased medical products based on the advice of friends or family members. We aggregate these improper practices into a single variable in the model, *Cultural and social influence on individuals regarding the use of medications*, which in most cases leads to *irrational prescribing.*

There are no clear-cut reasons as to why so much medication is going to waste in Saudi households. However, (Celik et al., 2013) stated that medication waste in Saudi Arabia and elsewhere may be due to patients' poor compliance, which results from *irrational prescribing* and other factors, including:

1) doctor- and healthcare professional-related factors: good *communication between doctor and patient* (Elzubier, 2002) is one of the crucial factors in improving medicine use and avoiding noncompliance originating at this stage of the care process;

2) *dispensing system*-related factors: in Saudi Arabia, patients can buy drugs *without the need of a formal prescription*. Moreover, the presence of a large number of medications on the market, some of which are readily available to patients at a *low cost or free* (because of government subsidies) (Colliers International, 2012; Rasooldeen, 2013) is another problem. Another incorrect practice that may influence decisions to purchase improper medical products is when pharmacists or other health practitioners go beyond their appropriate roles and diagnose symptoms and prescribe medicines (Abou-Auda, 2003), especially coupled with the lack of *controls over the selling of medications* in community pharmacies (Khan, 2014);

3) patient-related factors: the types of diseases that patients have, the level of education, and patient age, are all factors that can contribute to the problem. For the age factor, studies suggest that older patients, particularly adults 65 years and older, are major contributors to medication waste (Celik et al., 2013; Law et al., 2015). However, studies considering Saudi Arabia with reference to this factor are lacking. For this work, we disaggregate the Saudi population into two subpopulations: 1) individuals from 0-19 years of age, and 2) individuals 20 years of age and older. Only the older group is considered in this study (for reasons discussed below). Within the older subpopulation, only around 5% are 60 years of age or older (Almalki et al., 2011). Thus, we assume a parameter in the model, *Age coefficient*, so that the majority of the subpopulation considered and the potential individuals (in terms of age) that may be involved in waste are better represented in the model. This age factor will appear again in the discussion as well. The other two factors are not considered in this study, mainly because educational levels and disease types are irrelevant to the intervention policies. Our proposed interventions (as we will see later) have rather a different nature and focus; in this sense, these two factors are beyond the scope of this work. However, these factors are important and merit an independent study of their own.

These three sets of factors, along with the absence of effective *awareness* programs implemented within the care process (Celik et al., 2013; Law et al., 2015; Shi & Singh, 2014) all contribute to the problem of medication waste. We should mention that awareness programs presented during the care process can take place at the doctor consultation stage, while at a healthcare facility, or even when picking up medications at a pharmacy (Elzubier, 2002; Khan, 2014; Khalil & Elzubier, 1997; Law et al., 2015).

The life expectancy of a Saudi individual is about 75 years (World Bank, 2014a); however, the time horizon of the reference mode, Figure 5, only assumes the first 25 years of the life span of an individual in Saudi households. The dynamic behaviors of the reference mode reflect the contributions of an individual to medication waste. Saudi children start their lives being told to stay away from drugs (in common with many other children around the world). Therefore their contribution to waste is very low (and thus ignored); we assumed this period in the reference mode to be from 0-20 years. As time passes, the individual is influenced by other people's behaviors, attitudes and practices regarding the treatment of medicines, and this is expected to lead to a low *degree of compliance,* as explained earlier (Celik et al., 2013). By approximately age 20, an individual has fully formed his/her relationship with drugs and can make independent decisions, and this is where medication waste may start to occur. A high *degree of waste* in drugs is a result of collective and cumulative waste by Saudi households of individuals 20 years of age and older. That being said, the reference mode of the system can be constructed as shown in Figure 5, with its two key descriptive variables showing an inversely proportional relationship: lower *degree of compliance* implies higher *degree of drug waste*.

3.3 The Dynamic Model

The system dynamics (SD) method has been applied for decades to national level healthcare issues (Adam, Sy, & Li, 2011), with the main purpose being to study the relative effects of certain interventions or alternative assumptions,

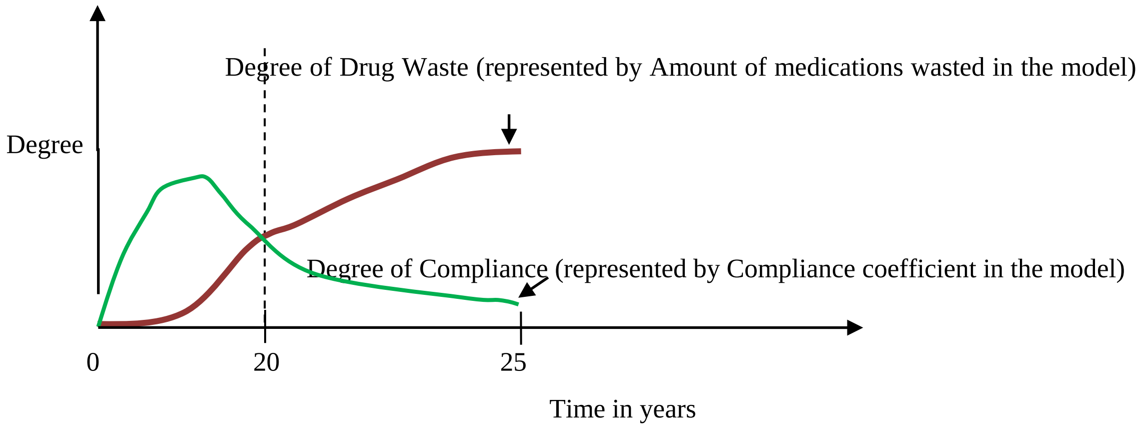


Figure 5: Reference mode for the variables of medication waste in Saudi Arabia reflecting the contribution per individual.

rather than accurately forecasting future values of the system. The SD technique attempts to discover behavioral patterns of key elements of the system over time, and it is among the top approaches used in tackling certain complex healthcare issues (flows during demand surges, for example) (Adam, et al., 2011; Manley et al., 2005). The work in (Homer and Hirsch, 2006; Marshall et al., 2015) discusses the use of SD in studying various problems in healthcare systems.

In our case, the problem is at the system level, and the model is developed not to precisely determine, say, the cost of wasted medications in the SHCS, but rather to reveal under what conditions the total cost could go higher or lower, which may assist in identifying policies to improve the situation. Specifically, SD will be used to evaluate the effectiveness of possible policies/interventions.

We developed the stock-and-flow model shown in Figure 6, which illustrates the key entities influencing medication waste in the SHCS, and their interrelationships. As discussed in previous sections, the model, which we developed using the Vensim environment (Ventana Systems, 2015), is based on a wide-ranging literature review, incorporating structural information and data found in (Abou-Auda, 2003; Al-Dhawailie, 2010; Al-Ghanim, 2004; Almalki et al., 2011; Celik et al., 2013; Colliers International, 2012; Elzubier, 2002; Khalil & Elzubier, 1997; Khan, 2014; Law et al., 2015; Shi and Singh, 2014). The parameter values are taken or inferred from (Abou-Auda, 2003; Al-Ghanim, 2004; Celik et al., 2013; Colliers International, 2012; Elzubier, 2002; Khalil & Elzubier, 1997; Khan, 2014). Further details will be provided in the discussion of the model. Again, the clauses written in *italics* represent state variables (stocks), flow rates, or coefficients in the model. Figure 6 shows the final model and its major feedback loops.

The Saudi population is disaggregated into three stock (state) variables in order to expose information related to the desired observed outputs: *Individuals involved in medication waste*, the *Amount of medication wasted* and the *Cost of wasted medication in the Saudi Healthcare System*.The population subsystem variables are: 1) the entire *Saudi population,* 2) *Individuals over the age of 20 years*, and 3) *Individuals involved in medication waste*. The initial values and parameter values for these three stock variables are taken from (Abou-Auda, 2003; Almalki et al., 2011; CDSISA, 2014; The World Bank, 2014b). The first two stock variables, *Saudi population,* and *Individuals over the age of 20* are involved in a reinforcing loop, i.e., a higher Saudi population would result in more people over the age of 20. The *Age coefficient* determines the potential *Individuals involved in medication waste* that may accumulate in the third stock variable. The subpopulation of *Individuals involved in medication waste* is dependent on the *Compliance coefficient*; if the compliance coefficient has a positive value (which is desired) then the large loop becomes a balancing loop, as it is assigned in the model. However, if the value of the *Compliance coefficient* is negative then we are instead in the noncompliance region where more individuals would be involved in medication waste. The components contributing positively and negatively to the *Compliance coefficient* were discussed in previous sections; additional information about their structure and data can be found in (Celik et al., 2013; Elzubier, 2002; Khan, 2014). For example, the *Dispensing system contributions* to the *Compliance coefficient* is influenced

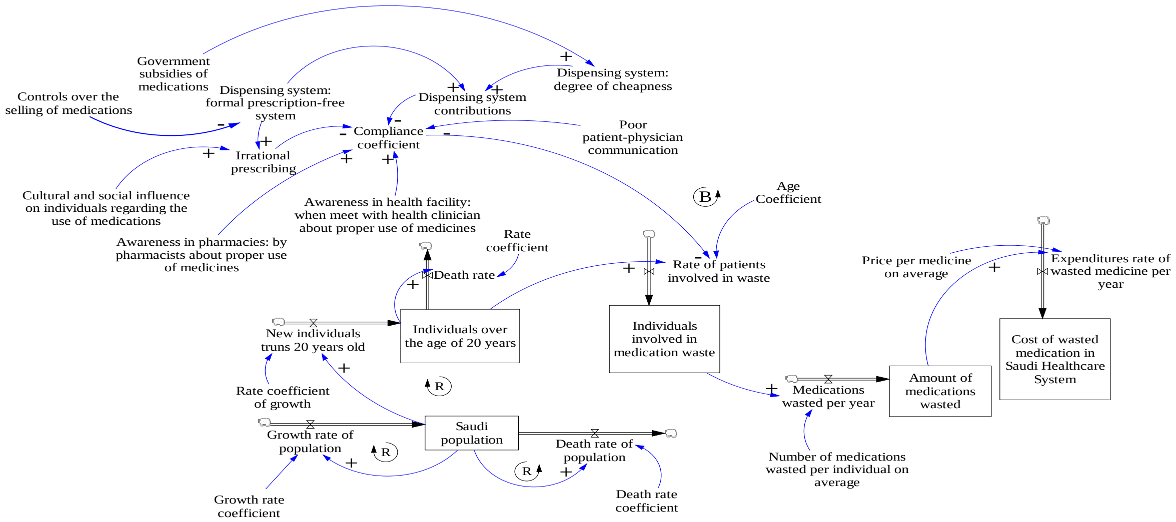


Figure 6: The system model.

by the medication *degree of cheapness*, which is itself influenced by the *Government subsidies of medications.* Another influence on the *Dispensing system contributions* is the lack of *Controls over the selling of medications*, which determines the value of the variable *formal prescription-free system.* For this, a look-up table tool is used in the Vensim simulation software to represent the dependency between *Control over the selling of medications* (independent) and *formal prescription-free system* (dependent). This latter route along with the *Cultural and social influence on individuals regarding the use of medications* affects *Irrational prescribing* as well, which is defined and discussed in the last section. *Irrational prescribing* behaviors have a negative influence on the *Compliance coefficient* (and thus the negative sign shown in the model). These variables highlight a phenomenon occuring in the SHCS and similar systems, where formal prescriptions are not actually enforced. This and the negative influence of government medication subsidies on the system should be restrained by *Control over the selling of medications*, which adversely affects the phenomenon of waste. However, the SHCS still suffers from the lack of controls, and thus this variable does not have a significant positive effect on the situation, at least at this point.

Poor patient-physician communication adversely affects the *Compliance coefficient* (Elzubier, 2002). For example, if a doctor rushes through a patient's appointment, the patient might feel less important and of less worth. This may lead the patient to lose faith in the doctor, stop his medications, and look for another doctor. In this case, the medication from the first doctor is considered a waste. However, *Awareness in health facility: when meeting with clinician about proper use of medicines* (Khalil & Elzubier, 1997), and *Awareness in pharmacies: by pharmacists about proper use of medicines* (Khalil & Elzubier, 1997; Khan, 2014) are also occasions during the care process when patients may be reached, and these opportunities can be used to improve the *Compliance coefficient* through specific educational programs.

Medications wasted per year solely depends on *Individuals involved in medication waste* that year. In other words, we would expect more of *Amount of medications wasted* to occur as *Individuals involved in medication waste* increases. *Amount of medications wasted* reinforces the variable *Cost of wasted medication in Saudi Healthcare System* (and thus the positive sign in the model). Data for these variables can be gathered from (Abou-Auda, 2003).

3.4 Proposed Policy Interventions

Our study and the development of the model shown in Figure 6 improve our understanding of the interactions existing between the elements of the system. The discussion in (Abou-Auda, 2003; Colliers International, 2012; Law et al., 2015; Shi & Singh, 2014) influenced our proposed interventions. In the following, we describe key (controllable) subsystems of the model, where we apply the interventions.

Subsystem 1: patients (or individuals) seeking medications. The proposed intervention is shown in blue, *Public-focused educational programs in medications' proper use and waste.* The focus is on education and increasing awareness, intervention learned from (Abou-Auda, 2003; Shi & Singh, 2014).

Subsystem 2: the government. The proposed intervention is in green. The Saudi government is advised to implement: 1) a *Copayment policy for medications*, 2) *Limiting the supported drugs* to a minimum, and 3)

Prohibiting the selling of medicines without formal prescriptions, and placing appropriate control mechanisms on over-the-counter medications (Colliers International, 2012; Rasooldeen, 2013; Shi & Singh, 2014).

Subsystem 3: pharmacists. Pharmacists in the SHCS are essential to this issue because of the way the system works: The pharmacist is the only specialist that must be seen in the process of buying/acquiring a medication in Saudi Arabia; everyone else can be optionally bypassed. Pharmacists are some of the most accessible health-care professionals and have an important role in improving rational drug use and compliance, which should in turn reduce medication waste (Celik et al., 2013). Pharmacists should be well prepared to educate individuals effectively about the rational use of drugs, because many irrational drug-related problems can be solved by education (Celik et al., 2013; Shi & Singh, 2014; Law et al., 2015). The intervention proposed, therefore, is during the patient's visit to the pharmacy; this is shown in red in the model, *Pharmacists' interventions: objective drug information.* This intervention may include: 1) information regarding the patient's medical conditions and medication(s) that is relevant, accurate, significant, easy to follow and clear, 2) using a patient's electronic medical record (if it exists) to evaluate the patient's purchase history, to avoid duplicate dispensing of medications, and 3) allowing the pharmacist to intervene if there are possible harmful drug interactions, which is a step in what is known as retrospective utilization review (Shi & Singh, 2014).

Subsystem 4: physicians. The intervention policy proposed is to create a designated time towards the end of the patient's visit in which the physician provides effective communication (Elzubier, 2002). It is referred to in the model (in orange) as *Patients-physicians effective communication program*. That is, patients should be provided with appropriate and clear information about their medical conditions and medications and the importance of medication compliance. The physician should also confirm that the patient understands the information.

A dynamic model with the subsystems described and the proposed interventions was developed, Figure 7. Notice that the proposed intervention *Patients-physicians effective communication program* and *Poor patient-physician communication* are both from the same domain. These may be related in different ways; we chose to combine them in the same term in the equation of the *Compliance coefficient*. The variables *Pharmacists' interventions: objective drug information* and *Awareness in pharmacies: by pharmacists about proper use of medicines* are treated similarly.

3.5 Model Validation

Based on the discussion by (Sterman, 2000), a battery of tests was performed on both models for validation purposes, including: 1) model boundary tests, 2) structural assessment tests, 3) dimensional consistency tests, 4) extreme conditions test, 5) behavioral reproduction and hypothesis testing, and 6) sensitivity analysis conducted including parameters lacking data, such as *Age coefficient*. The outcomes of the validation processes and testing variations indicate that the model is reasonably insensitive.

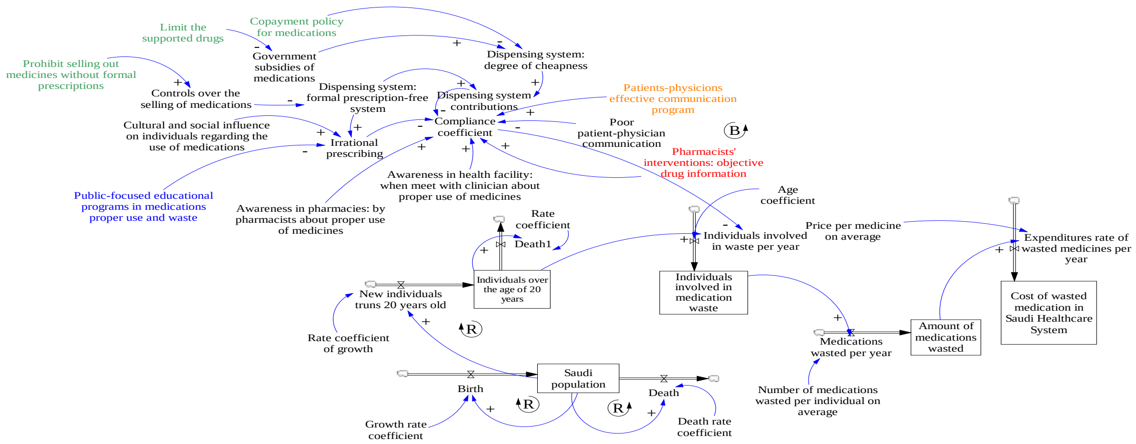


Figure 7: Dynamic model with the proposed interventions.

3.6 Results

Figures 6 and 7 illustrate the model developed in this study before and after applying the proposed interventions, respectively. Notice that the *compliance coefficient* variable is a hub and is crucial to both models; it is expected to have a value in the interval of [-1,1]. Negative values represent the poor compliance region, whereas positive values indicate a higher degree of compliance. The zero value is neutral. The model in Figure 6 (before applying the interventions) made a value for the *compliance coefficient* of -0.8, which indicates (as expected) a high degree of noncompliance. However, when we applied the proposed interventions, the value of *compliance coefficient* moved from the negative region to the positive (0.01), indicating improvement in the compliance degree among Saudi individuals. The results of runs before and after applying the interventions are presented in Table 1. The variable *Individuals involved in medication waste* showed improvement as a result of the proposed policies and program interventions. The improvement of *Individuals involved in medication waste* reduced the value of the *Amount of medication waste* and *Cost of wasted medication in SHCS.* During the course of examining the interventions, we found that educational programs and awareness interventions were more successful in reducing the number of individuals engaging in waste than other interventions, including: 1) introducing a copayment policy for medications, 2) reducing government subsidies for drugs, and 3) putting more controls on medication sales, although these interventions also showed considerable effectiveness. The results suggest that the SHCS would benefit from reevaluating their policies and programs as proposed in this study.

Table 1 Simulation results, before and after SHCS interventions, where improvements are achieved. The simulation represents a total of 5 years.

	Values before interventions applied (difference between the beginning and end of the period)	Values after interventions applied (difference between the beginning and end of the period)	Unit	Note
Saudi Population	~ 2.98 million individuals (Growth)	~ 2.98 million individuals (Growth)	Individual	Same population growth
Individuals over 20 years of age	~ 2.78 individuals (Growth)	~ 2.78 individuals (Growth)	Individual	Same population growth
Individuals involved in medications waste	~ 10.2 million individuals (growth)	~ -130,000 individuals (decay)	Individual	Improved
Amount of medications wasted	~ 43.8 million medications	~ 23.8 million medications	Each	Improved
Cost of wasted medication in Saudi Healthcare System	~ $1,006.6 million	~ $789 million	US Dollar	Improved

4. Implications for the US Healthcare System

The US healthcare system (USHCS) is more advanced than the SHCS in several aspects, including: dispensing systems, facilities planning, maturity in policies, and ratio of healthcare professionals to patients. However, it shares the issue of medication waste (Celik et al., 2013). The projected total national cost due to medication waste exceeds $2.4 billion per year in the USHCS (Law et al., 2015). Furthermore, it is estimated that 2 out of every 3 prescription medications were unused (Law et al., 2015). The study also indicates that the reasons for the nonuse of prescription medication in US households are not clearly identified.

We performed a comparative study of the factors contributing to medication waste and poor compliance between the SHCS and the USHCS. We found that the USHCS is more robust in (terms of the factors) than the SHCS. However, we were surprised to find that the USHCS has a higher ratio of medication waste cost to population (6.4) (Law et al., 2015) compared to the SHCS (4.76) (Abou-Auda, 2003). The comparative study included components such as: control and supervision of medicines, the requirement for formal prescriptions, electronic systems of patient records, and government copayments and regulations related to support and subsidies for medications. For these components, the USHCS was again found to be much more mature. However, patients' degree of compliance and the rational use of medication remain in question. Here, it should be recalled that it is the consensus of the literature (Celik et al., 2013; Khan, 2014; Shi & Singh, 2014) that most of the medication waste problems, including poor compliance and irrational use, can be solved by appropriate education. The US government understood this correlation more than two decades ago; the Omnibus Budget Reconciliation Act of 1990 states that pharmacists are required to give consumers all necessary information about drugs/medicines and their possible misuses. Shi and Singh (2014) stated "This education and counseling role of pharmacists is broadly referred to as pharmaceutical care." Clearly the United States has put the greater responsibility for patient education and awareness with reference to medications on pharmacists, which is the expected approach given the nature of the USHCS. This law should enforce practices that would be expected to naturally lead to a higher degree of compliance and rational use of medication, but a number of studies raise doubts about its effectiveness (Celik et al., 2013; Law et al., 2015).

At a later stage of our comparative study, we applied a bivariate-based analysis involving: 1) level of compliance, and 2) patient age. In the course of collecting data, we learned that out of 4 billion prescriptions filled in the US in 2007, elderly patients wasted more than $1 billion worth of drugs (Celik et al., 2013). Over 12.4% (Shi & Singh, 2014) of the US population consists of older adults (65 years and older); in Saudi Arabia they comprise around 5% of the population (Almalki et al., 2011). Thus, the subpopulation of elderly patients in the US appears to make an outsized contribution to the overall cost of medication waste, and this could have important policy implications. Therefore, the USHCS should consider investigating how much each category of the population (children, younger adults, older adults, women, disabled, etc.) contributes to medication waste. And if, as we anticipate, older adults are found to contribute disproportionately, then educational and other suitable programs should be developed and effectively delivered to the targeted subpopulation. Any program that successfully provides objective drug information, i.e., information that is relevant, accurate, clearly presented and leads to rational use, is likely to be beneficial.

5. Conclusions

The SHCS has been successful in accomplishing a great deal in the relatively short time since its founding, and appears to be on track for further advances in both quantity and quality. The ability to meet future demand, in a way that ultimately results in satisfactory outcomes, would seem to require a comprehensive approach to creating a healthcare system in which utilization is optimized, drug waste is reduced, and quality is improved. The problem of wasted medicine in Saudi households is one example of a problem that needs to be addressed. We have discussed the extent of medication waste and the dynamic causes contributing to the problem, and built a dynamic model in order to enhance our understanding of the problem. The model was analyzed, points of interventions were identified, and proposed interventions were applied, demonstrating how improvements to the system could be realized. Although our model is tailored to the SHCS and systems with similar features (e.g., government subsidies of medications), it can also be a foundation for more general models. There are three components of the model in particular that are likely to appear in very similar fashion in related models: 1) compliance coefficient as a hub variable influenced by certain factors, 2) subpopulations that are involved in medication waste, and 3) amount of medication waste.

Noncompliance and medication waste were investigated for both the SHCS and the USHCS, and recommendations were provided and discussed for both systems. We found that the SHCS needs to reconsider a number of its policies and practices, in particular, control of medication dispensing, government subsidies to support the provision of medications, and awareness programs for all ages. In the case of the USHCS, we anticipate based on a comparative analysis that a large proportion of medication wasted can be attributed to older adults. Therefore, the USHCS ought to consider developing programs of education and awareness suited to this group in order to improve the degree of compliance and rational use of medication.

Future work may focus on a detailed economic study that addresses the cost of interventions, the cost of drug waste, and potential savings as a result of policy interventions.

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Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Wireless Multimedia Sensor Network Reliability Analysis with Petri Nets

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Abstract

Petri Nets (PNs) are used as a tool to specify, model, design, manage and evaluate distributed systems and have applications in manufacturing, command & control, communication, computer and logistics network systems. PNs deal with problems as production planning, scheduling, process modeling, data analysis, simulation, work flow, system design, etc. One of the problems that PNs are used for is the reliability analysis of the systems. In this work, PNs are used to analyze the network reliability of a Wireless Multimedia Sensor Network (WMSN). Since the WMSN structure is different than other systems, the PN elements have different roles in the model of a WMSN. In our previous works, a Monte Carlo (MC) simulation is used to estimate the reliability of a WMSN. In this paper, PN and MC simulation methods are compared. PIPE 4.3 software is used to design the PN model of a WMSN and MATLAB is used to code the MC simulation.

Keywords

Petri nets, wireless multimedia sensor networks, network reliability, Monte Carlo simulation

1. Introduction

Petri Nets (PNs, sometimes called place-transition nets or P/T net) are directed bipartite graphs which were first proposed by Carl Adam Petri (1962). PNs combine a well-defined mathematical theory with a graphical representation of the dynamic systems. The theoretic side of PNs provides precise modeling and analysis of the system behavior while the graphical representation of PNs facilitates visualization of the modeled system state changes. The success of PNs is related with this integration (Wang, 2007).

PNs are used as a tool to specify, model, design, manage and evaluate especially distributed systems and have applications in manufacturing, command & control, communication, computer, and logistics network systems. PNs deal with problems as production planning, scheduling, process modeling, data analysis, simulation, workflow, system design, etc. (Proth & Xie, 1996; Tuncel & Bayhan, 2007; Wang, 2007; Zhang et al., 2011).

Since 1962, various formats and several algorithms have been studied extensively in PNs such as Timed Petri Nets (TPNs), Stochastic Petri Nets (SPNs), Queueing Petri Nets (QPNs), Coloured (or typed) Petri Nets (CPNs), etc. (Bause & Kritzinger, 2002). PNs in which random firing delays are associated with transitions whose firing is an atomic operation are known under the name SPNs (Marsan, 1989). TPNs have the capability of handling quantitative time and CPNs have colored (valued) tokens to analyze high-level nets (Van der Aalst, 1992).

One of the problems that PNs are used for is the reliability analysis of the systems. In our previous works, a Monte Carlo (MC) simulation is used to estimate the reliability of a Wireless Multimedia Sensor Network (WMSN). In this paper, PNs are used to analyze the reliability of a WMSN and both methods are compared.

The rest of the paper is organized as follows. The next section describes the applications of PNs in reliability analysis. In Section 3, the reliability calculation matter in WMSN is presented. Section 4 summarizes the data flow process of a sample WMSN with a PN model. Finally, Section 5 concludes this paper.

2. Petri Nets and Reliability

Reliability can be defined as the conditional probability that a system operates correctly and completes its functions in a time interval (Abd-El-Barr, 2007). PNs are used to analyze the reliability of the several systems in the literature.

PNs have four types of elements called transitions (signified by bars, rectangles), places (signified by circles), arcs (signified by arrows) and tokens (signified by marks, black dots). Transitions represent either operations or events; places represent buffers or conditions and tokens represent parts or resources. The tokens allow us to model the dynamics of the system. Directed arcs connect places to transitions or transitions to places. A directed arc never connects a place to a place or a transition to another transition (Proth & Xie, 1996; Bause & Kritzinger, 2002).

Formally, a PN is a five-tuple PN = (P, T, A, W, M_0) (Proth & Xie, 1996):

$P = \{p_1, p_2, p_3, \dots, p_n\}$ is a finite set of places,

$T = \{t_1, t_2, t_3, \dots, t_q\}$ is a finite set of transitions,

$A \subseteq (P \times T) \cup (T \times P)$ is a finite set of arcs,

$W: A \rightarrow \{1,2,\dots\}$ is the weight function attached to the arcs,

$M_0: P \rightarrow \{0,1,2,\dots\}$ is the initial marking.

Note that $P \cap T = \emptyset$. A PN without marking is denoted by $N = (P, T, A, W)$. Thus PN = (N, M_0). When all the weights are equal to 1, the PN is said to be ordinary. If M_0 is the initial marking of a PN, then $M_0(p)$ is the number of tokens in the place of the PN (Proth & Xie, 1996). A sample PN is presented in Fig.1.

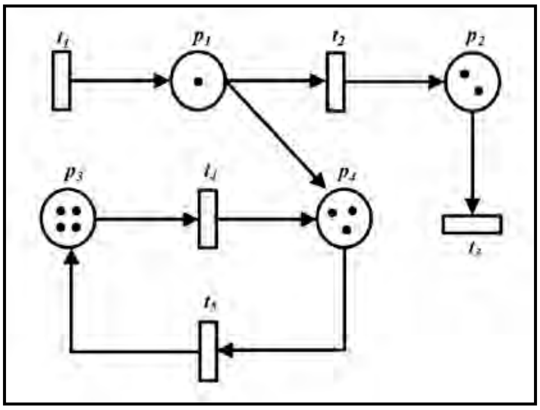


Figure 1: A sample PN

In the area of PN based reliability analysis, Fricks & Trivedi (1997) study the effect of failure dependencies in reliability models developed using SPNs and continuous-time Markov Chains. SPNs are also used for the simulation of the fault diagnosis process of oil-immersed transformers, and the definition of the actions followed to repair the transformer by Georgilakis et al. (2006). Correspondingly, Sachdeva et al. (2008) presented some basic PN models to analyze the reliability of the dynamic industrial systems. In the paper, it is shown that PNs can be effectively used to model and analyze the behavior of dynamic repairable systems. Aized (2010) models and analyzes random failures of processing modules of multiple cluster tool systems using CPN method. Yang et al. (2011) present a PN based reliability evaluation model to analyze the working principles of the hydraulic variable pitch system of a wind turbine. Another study by Xia et al. (2013) proposes a probabilistic method for reliability analysis of Ontology Web Language for Services processes employing the non-Markovian SPN as the fundamental model. Signoret et al. (2013) presented another study to deal with the graphical aspects of PNs, and they proposed some guidelines to structure and improve the drawing of standard PNs. The work describes the Reliability Block Diagrams (RBD, respectively flow diagrams) driven PNs which are very effective to model safety systems. Extended SPNs are used for reliability modeling and evaluation of electric vehicle motor by Wang et al. (2014). Another paper presented by Zhang & Yao (2015) includes a general method of analyzing the reliability of multi-state systems using Fuzzy SPNs, and Generalized SPNs are also used for analyzing the dynamic reliability of a jet pipe servo valve by Chu et al. (2015).

The reliability issues in network-based systems with PN models are also studied in the literature. Kumar & Aggarwal (1989) introduce a PN based approach to determine all spanning trees for overall reliability analysis of general networks. Mandaltsis & Kontoleon (1989) also use PN to enumerate all K-trees and K-cutsets and its application on K-terminal network reliability evaluation. approach to determine all spanning trees for overall reliability analysis of general networksapproach to determine all spanning trees for overall reliability analysis of general networksapproach to determine all spanning trees for overall reliability analysis of general networksAghasaryan et al. (1998) propose to use of the concurrence of events to separate and simplify the state estimation in a faulty system. PNs and their causality semantics are used to model concurrency. Special partially SPNs are developed, that establish some equivalence between concurrence and independence. Callou et al. (2012) propose a set of formal models for quantifying dependability metrics for data center power infrastructures. The adopted method incorporates a hybrid modeling technique that considers the advantages of both SPNs and RBDs to evaluate system dependability. A new reliability modeling method for network systems based on Generalized SPN is also studied by Chen et al. (2012). Soares & Vrancken (2012) model the dynamic behavior of a group of traffic signals controlling a network of intersections by PNs, which is a complex discrete event system. The PN model reveals a components-based design, which increases modularity and reduces complexity. Reliability is investigated by Vahebi et al. (2013) in Grid services, and through using PNs, a model is proposed for computing as well as increasing reliability in Grid networks. Another PN simulation including fuel cell modeling techniques has been adopted to develop an accurate degradation model by Whiteley et al. (2015). Operational parameters such as water content, temperature and current density and their effects on the occurrence of failure modes can be modeled through their technique. In another study, the idea that the comprehensive knowledge representation should be established for fault diagnosis is suggested by Wang et al. (2015). In the paper, PNs are used for logical reasoning by knowledge representation, which can be used to judge fault elements accurately even when the protective relays and circuit breakers malfunction.

In the area of communication and computer networks, Bhat & Kavi (1987) overview the reliability models of computer systems with data flow graphs including PNs. PNs and data flow graphs facilitate the analysis of complex computer systems by providing a convenient framework for reliability analysis. Balakrishnan & Trivedi (1996) advocate the use of stochastic reward nets (a variant of SPNs) for the concise specification, automated generation and solution of alternate-routing protocols in communication networks. Henry et al. (2010) present Coupled PNs for risk analysis. The paper presents a framework for quantifying the risk induced by the potential for cyber-attacks levied against network supported operations. Cho et al. (2010) developed mathematical models based on SPNs to identify the optimal rate for intrusion detection system execution to maximize the mean time to failure of the system, when given a set of parameter values characterizing the operational conditions, and attacker behaviors for Wireless Mobile Ad-hoc Networks (WMANs). Guimaraes et al. (2011) investigate the dependability modeling of computer networks with redundancy mechanism and use SPNs as an enabling modeling approach for analytical evaluation of complex scenarios. Meligy et al. (2012) propose a method to model the internet host reliability with TPNs. A PN-based simulation model of a WMAN is also developed and studied by Kostin et al. (2014). Their model covers all the fundamental aspects of the behavior of such a network and uses a novel scheme of orientation-dependent (or sector-dependent) internode communication, with random states of links. Jamro et al. (2015) present a model of a communication subsystem with Timed CPN formalism. The communication tasks in distributed control systems are tested with PN. In another paper, a novel PN modeling methodology for accurately calculating the reliability of wireless CORBA network is proposed by Koreim et al. (2015). A Generalized SPN performance model is presented for describing the different communication pattern that can occur among the various network resources under the execution of parallel tasks.

A study related with PNs and Wireless Sensor Networks (WSNs) is done by Lee (2008), and he proposes that PNs can be used to model the operated behaviors and to synthesize the command filters for supervision in Semiautonomous Mobile SNs. Furthermore, Yu et al. (2011) propose a reliable energy-efficient multi-level routing algorithm in WSNs. In the algorithm, a knowledge-based inference approach using fuzzy PNs is employed to select cluster heads, and then the fuzzy reasoning mechanism is used to compute the degree of reliability in the route sprouting tree from cluster heads to the base station. Another study on WSN subject is done by Babaie et al. (2013). In the paper, the behaviors of the components of a sensor are independently analyzed using the proposed model based on PNs and the links of the sensor’s components are investigated using the correlation graph. In another paper, a Fluid SPN modeling framework is presented to provide an extensive evaluation of all the factors that contribute to the energy dissipation in mobile wireless sensor nodes (D'Arienzo et al., 2013).

As can be seen, there are several applications of PNs with different network types. However, as far as we can figure out that there is not any study about PNs with WMSN reliability together. In this paper, we intended to close this gap in the literature. The next title expands the WMSN reliability.

3. Wireless Multimedia Sensor Networks and Reliability

WMSNs are a particular type of WSNs in which sensor nodes are small cameras and microphones. WSMNs differ from WSNs. WSN nodes collaborate to get scalar data such as pressure, temperature, humidity, or light to the base station. The sent data from WMSN nodes are multimedia data such as voice, image, or video. Even so, scalar data can also be collected by a WSMN, by including the required sensor nodes (Azim & Jiang, 2016).

Network reliability is the expression of the probability for network operations. Nonetheless, WMSN reliability differs from the network reliability of WSNs and traditional communication or computer networks. Regarding WMSN and WSN reliability, sensor deployment densities are much higher than the traditional network densities. The high density increases the complexity of network reliability problem. Another difference between traditional and sensor networks is the data traffic flow. In traditional networks, the flow is peer to peer, however, in sensor networks, data relays from the target nodes to a central base station (sink). The flow also affects the network reliability of sensor networks. Since the deployment of nodes and links, connectivity between them, reliability values of links and nodes are considered to calculate the network reliability of WSNs and traditional network types, additionally WMSN reliability formulation has to include the coverage values of sensors (cameras). Moreover, the coverage has conic shape. In WSNs, the coverage is circular. These differences refer to make a new definition for WMSN network reliability measure. Therefore, in our previous work (Ozkan et al., 2015), we made a new reliability definition for WMSNs.

In Ozkan et al. (2015), an MC simulation is used to calculate the WMSN reliability as the gathered information from terrain such as Fig.2. The WMSN is deployed in an enemy zone to get surveillance from observed targets. The targets have importance values between [0-1], and total WMSN reliability is the total gathered information value from the terrain. The complete information on terrain is the total importance values of targets. The proposed MC simulation is presented below in Table 1, and it tries to compute the probability of network operations of WMSN. Since connectivity and coverage are vitally important for WMSN, the MC is considering the connectivity of sensor nodes to the base station by deleting the failed nodes in replications. The deletions of failed nodes are done by the comparison of random numbers with the reliability values of nodes. The coverage value is the gathered surveillance data from the targets when the up and running nodes deliver the data to the base station.

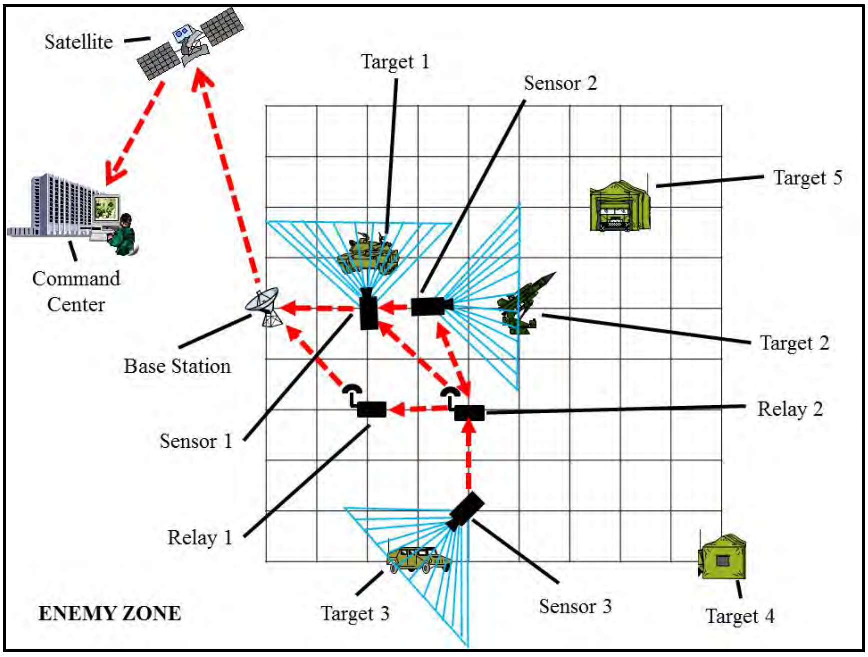


Figure 2: A sample of surveillance data flow in a WMSN to get surveillance from an enemy zone

Table 1: MC Simulation

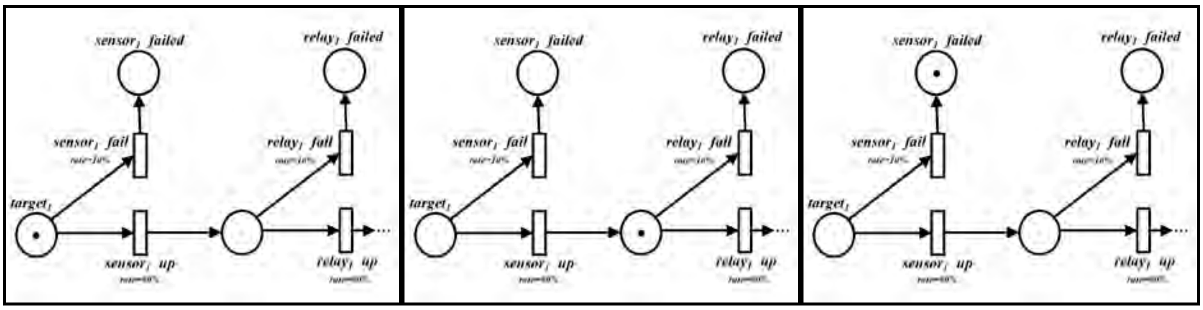
Step 1. Perform following steps *nr* times
- 1.1. Perform the following steps for each sensor and relay nodes (*j*) on deployment point *i*
  - 1.1.1. Generate random number u_i from U (0,1).
  - 1.1.2. If u_i < *Sensor or Relay Reliability* then $x_i = 1$ else $x_i = 0$.
  - 1.1.3. If $x_i = 0$, delete all links of the sensor or relay *j*
- 1.2. Perform the following steps for each target (*k*)
  - 1.2.1. *Estimated i-k Reliability* = 0.
  - 1.2.2. Perform the following steps for each sensor *j* on point *i* covering target *k*
    - 1.2.2.1. If the sensor *j* is connected to the base station and *Sensor Reliability* > *Estimated i-k Reliability*, assign source-sink network reliability as; *Estimated i-k Reliability = Sensor Reliability*;
- 1.3. Compute the source-sink network reliabilities for all targets as; *Estimated i-k Reliabilities*
- 1.4. Estimate reliable information gathering as; *Estimated WMSN Reliability* = ∑ *Estimated i-k Reliabilities * Importance values of covered targets / Total importance values of all targets*

Step 2. Compute reliable information gathering as; *WMSN Rel IG* = ∑ *Estimated WMSN Reliabilities / nr*

In the sample of Fig.2., the importance values of targets are 0,95 ; 0,85 ; 0,75 ; 0,15 and 0,06 respectively. As seen from the Fig.2, there are 5 targets on terrain and 3 of them are in the coverage area of WMSN. The collected surveillance data by sensors (cameras) are delivered to the base station via other sensor and relay nodes. The red dashed arcs are presenting the links between the nodes. Some of the links are directed, one of them is bidirected compatible with the data flow from sensors to the base station. The base station is connected to command center via satellite. In the sample, the node reliability values are assumed as 0,9 which means they are 90% operational. However, the links are always working. The proposed MC simulation calculates the reliability of the sample WMSN as 0,7532 with 95% confidence level (*nr* (repetition number) = 5000) in 0,2 seconds. Consequently, the WMSN can collect 75% of the complete information (total importance values of all targets = 2,76) from the enemy zone. MATLAB is used to code the MC simulation. In the next title, a PN is used to analyze the network reliability of the sample WMSN presented in Fig.2.

4. A Petri Net Model to Analyze the Reliability of a Wireless Multimedia Sensor Network

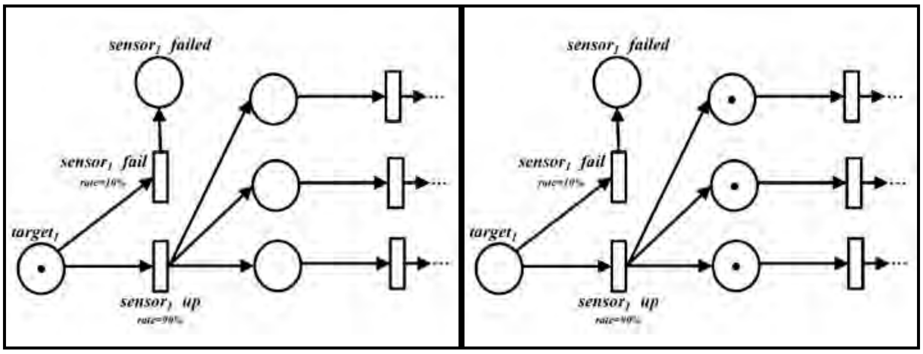
Since a WMSN structure is different than a manufacturing system, the PN elements have different roles. In the presented model, the transitions of PN represent up and fail operations of sensor and relay nodes of the WMSN. Places represent the targets, base station, operating and non-operating conditions of sensor or relay nodes. Correspondingly, arcs represent the connections between the transitions and places. Lastly, a token represents a surveillance data package collected from a target. A sensor observes a target and gets surveillance data (token) from the target, then delivers this surveillance data to the base station via other sensor or relay nodes. Since sensor and relay nodes have reliability values, they can sometimes fail and the data can be lost. Some samples for transitions, places, arcs and possible states are presented in Fig.3.



(a) **(b)** **(c)**

Figure 3: (a) Target 1 has a data package (a token) (b) Sensor 1 is up, the data is transferred to Relay 1 (c) Sensor 1 is failed, the data is lost

In a sensor network, a sensor or a relay node can be connected to more than one node at the same time. This occasion can be seen in a PN as presented in Fig.4. In Fig.4, a sensor is connected to three relay nodes. If the sensor is working (up), then it fires the taken data to the following relay nodes. This fire copies the data and one taken token reaches to the relay nodes as three copied token (data).



(a) **(b)**

Figure 4: (a) Target 1 has a data package (a token) (b) Sensor 1 is up, the data is transferred (copied) to three relay nodes

The PN model of the sample WMSN is proposed in Fig.5 and PIPE 4.3 software is used to design. Since *Sensor 1* and *Sensor 2* has two roles in WMSN such as observing a target and transmitting the taken data, two couples of transitions are disposed of the PN (i.e. *Sensor 1-Up/Fail* and *Sensor 1_1-Up/Fail*). There are three targets covered by three sensors in WMSN sample. Therefore, three first places are generated for targets. A place is also set as the base station to the right side of the PN. The initial marking vector is set to M_0 = [*Target 1, Target 2, Target 3, Sensor 1-Failed, Sensor 2-Failed, Sensor 3-Failed, Sensor 1_1-Failed, Sensor 2_1-Failed, Relay 1-Failed, Relay 2-Failed, P1, P2, P3, P4, Base Station*] = [5000, 5000, 5000, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]. The targets have 5000 tokens at the beginning of simulation similar to repetition number in MC simulation. The node reliabilities are assumed as 0.9. Therefore, the rates of up transitions are set to 90%, and the rates of failed transitions are set to 10%. Furthermore, as can be seen from the Fig.5 that *Relay 2- Up* transition is connected to *P1, P2* and *P3* places which mean if *Relay 2-Up* fires, it transmits (copies) the taken data into three places. This occasion increases the number of tokens in the PN while simulating.

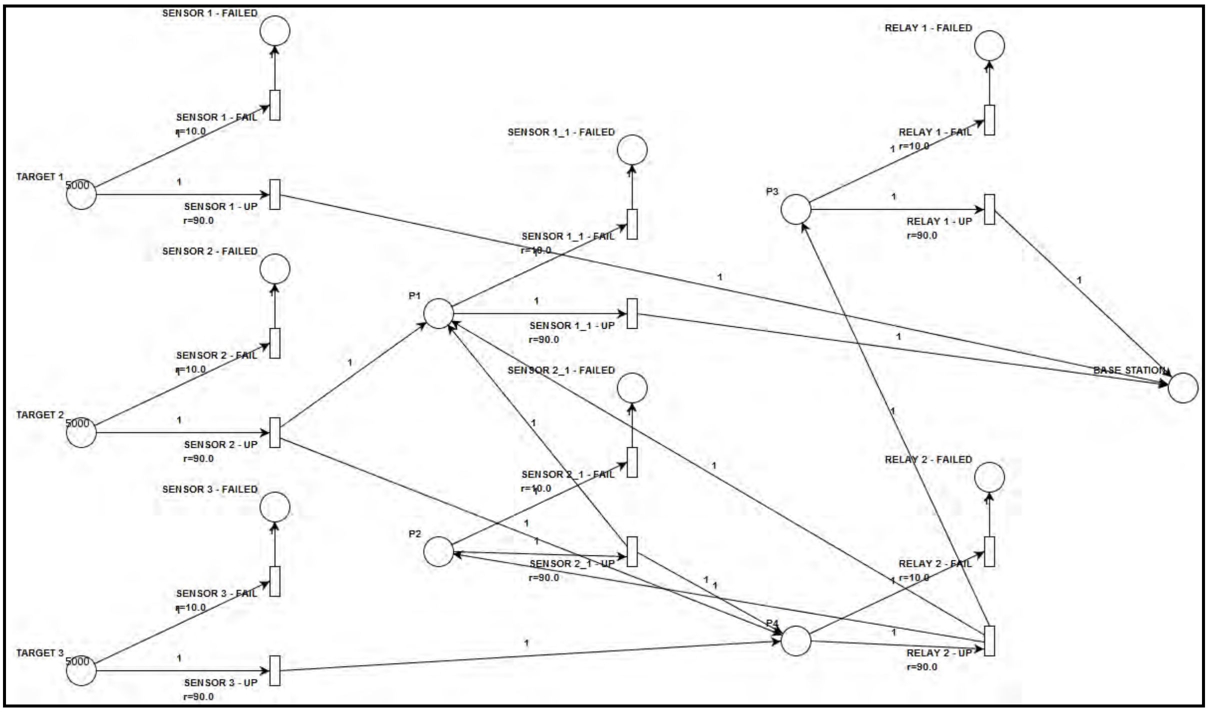


Figure 5: PN model of the sample WMSN

In the experimental design, the PN model is simulated for 15000, 20000, 25000, 50000 and 100000 numbers of firings respectively with ten numbers of repetitions. The CPU times of simulations are ranging from 4 to 26 minutes. After all firings, the average numbers of tokens in the targets, passing places (*P1, P2, P3, P4*) and base station are presented in Table 2, the average number of tokens in the failure places of nodes are presented in Table 3.

Table 2: Results of PN simulations for data flow

Number of firings	Average number of tokens for 10 repetitions							
	Target1	Target 2	Target 2	P1	P2	P3	P4	Base Station
15000	3907	3899	3873	1746	5	6	1789	2867
20000	3568	3489	3475	2393	6	7	2453	3787
25000	3165	3139	3143	2943	7	8	2941	4757
50000	1730	1718	1702	5713	10	9	5126	9738
100000	839	856	839	10701	9	10	5634	20692

Table 3: Results of PN simulations for failures

Number of firings	Average number of tokens in failure places for 10 repetitions						
	Sensor 1	Sensor 2	Sensor 3	Sensor 1_1	Sensor 2_1	Relay 1	Relay 2
15000	100	118	104	117	111	105	96
20000	146	154	135	129	136	127	149
25000	192	196	191	189	188	160	192
50000	334	343	315	413	363	364	420
100000	409	410	402	996	874	860	971

In Table 2 and 3, the average numbers of tokens in the targets are decreasing while the number of firings is increasing as expected. The average number of the tokens in the base station is also increasing because of the increase of tokens in the network. The number of tokens in the base station is more than 15000 for 100000 firings. Besides, some of these tokens in the base station are representing the same data. More importantly, the PN model helps to understand the surveillance data flow and identify the sensor and relay nodes which have vital roles to accomplish the mission of the WMSN. The results reveal that since the reliability values of *Sensor 1, Sensor 2* and *Sensor 3* are the same (0,9), they have similar attitudes in simulations while observing targets. However, there are much more data flow on *P1* (transfer duty of *Sensor 1*) and *P4* (*Relay 2*) therefore they are more critical nodes than others to succeed the missions. While designing the WMSN, there can be created new alternatives nodes and routes to back up these two nodes will improve the reliability value of WMSN. Moreover, because of the failure rates are same for all nodes, they have almost the same behaviors and the average numbers of the tokens in the failure nodes are close. In the example for 15000 firings, *Sensor 1* has lost almost 10% of surveillance data (100 tokens of 5000-3907 tokens) while observing *Target 1* when it fails. Since *Target 1* has 0,95 importance value which means it has 0,95*100/2,76 = 34% of total information on terrain, *Sensor 1* loses 3,4% information on the terrain when it fails. Exclusively, the tokens in the *Sensor 1_1*, *Sensor 2_1*, *Relay 1* and *Relay 2* are higher than the others as they are transferred nodes in the data flow. Consequently, the analysis of WMSN with PN provides a lot of information about the data flow and the roles of the nodes in WMSN. Therefore, this reliability analysis has a vital role in the design of a WMSN.

5. Conclusion

In this paper, PN and MC simulations are used to analyze the reliability of WMSN. The MC simulation provides a single number for the reliability of WMSN in seconds. The number indicates the probability rate of WMSN operations. However, the MC cannot provide detailed information about the data flow and roles of the nodes in the WMSN. A PN can be used for this purpose. Analysis with PN can figure out the data flow and the important vital nodes. These details can be used to improve the reliability of the WMSN. In the design of a WMSN, MC simulations can be used especially in iterative methods to save some time. Then PN simulations can improve the suggested design and can provide feedback to the iterative methods. In this work, MC simulation is coded in MATLAB and PN simulations are done with PIPE 4.3 software. For the future directions, colored tokens can be studied to get more explanatory information in the design of more reliable WMSNs.

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A Genetic Algorithm for the P-Median Facility Location Problem

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Abstract

The p-median problem is one of the most well-known facility location problem and have several applications in transportation, distribution, location of public, warehouses etc. The objective is to locate p facilities (medians) such that the sum of the distances from each demand point to its nearest facility is minimized. The p-median problem is well known to be NP-hard and several heuristics have been developed in the literature, but there are few applications of genetic algorithms for this problem. In this study, a new genetic algorithm approach to solve uncapacitated p-median problem is proposed. The parameters of the genetic algorithm are tuned using design of experiments approach. The proposed algorithm is tested on several instances of benchmark data set and evaluated with optimal solutions of the problems.

Keywords

P-median problem, facility location, genetic algorithm, heuristics

1. Introduction

P-median problem is a well-known discrete optimization problem aiming to locate p number of facilities that satisfies the demand of multiple places with minimum cost. Besides, the p-median problem is a network problem that was originally designed for, and has been extensively applied to facility location. The search for p-median nodes on a network is a classical location problem. In the supply chain context, distribution of goods from decentralized warehouses is more beneficial than that from a central warehouse (Satoglu et al., 2006). Besides, p-median problem has been studied for solving the cell formation problem (Behret and Satoglu, 2012).

The p-median problem is an NP-hard combinatorial optimization problem, because of this reason, if the problem size is increase, it is getting harder to obtain optimum solution via the mathematical models. There is a large number of studies on the p-median problem in the literature. Reese (2006) reviewed the past studies according to the problem type and the solution methods employed. Later, Mladenovic et al. (2007) assessed the meta-heuristic studies that intended to solve the p-median problem. Summary of the p-median studies are summarized in the literature review section of this study.

The aim of this study is to develop a new Genetic Algorithm (GA) to solve the p-median problem that can reach optimal or near optimal solutions. The unique aspect of the study is that first an Initial Solution Algorithm is employed to reach good beginning solutions. Thus, the algorithm can reach solutions equal to or very close to the optimum. Moreover, a 3^3 Full Factorial Design is performed where three levels are selected for the factors of the probability of mutation, the population size and the number of iterations, and parameter tuning is performed to reach a better performance. The objective values and the CPU times are considered as response variables. For each parameter level, the proposed GA is run five times. By using the GA solution results, MANOVA and Post-Hoc Tests are performed, to identify whether the performance difference between selected parameter levels are statistically significant, for each problem. Hence, significant parameter levels are determined and input into the algorithm. The proposed GA is tested on the well-known data set presented in the *OR-Library* which consist of 15 instances with up to 100 medians and 300 demand points. In addition, the results are compared with those of another GA in the literature which is presented by Alp et al. (2003).

The paper is organized as follows: The p-median studies and those that used GA for the p-median are reviewed in the literature review section. Later, the proposed GA that is integrated with the Initial Solution Algorithm is explained in Section 3. In Section 4, parameter tuning and experimental design stages are explained for the selected data set. The computational results are presented and discussed in Section 5. Finally, the conclusion and future research are presented.

2. Literature Review

Over the past 10 years, there has been a dramatic increase in the amount of literature on solution methods for the p-median problem. Several heuristic and metaheuristic methodologies were developed to solve the p-median problems by the researches. In the field of the heuristics, Rolland et al. (1996) proposed a tabu search algorithm for the p-median problem. In the algorithm, long term and short term memory, strategic oscillation and random tabu list sizes were used. Results of the algorithm were compared with two other heuristics to show its performance. Beltran et al. (2006) proposed a Semi-Lagrangean relaxation approach to the p-median problem. It was tested by solving large-scale instances and the best known dual bounds for five of the six non solved difficult problems were improved. Avella et al. (2012) developed an aggregation heuristic for the large size p-median problems. The authors introduced a new heuristic for large-scale p-median problem instances based on Lagrangean relaxation. Dzator and Dzator (2013) proposed a new heuristic for the medium size p-median problems and applied to an ambulance location problem. A reduction and an exchange procedure are used in the heuristic and 400 randomly generated problems and 6 well known test problems are used to test the proposed methodology. Sevkli et al. (2014) developed a new discrete particle swarm optimization (PSO) algorithm for the p-median problem. The PSO algorithm was tested on benchmarking problem instances from *OR-Library* and its performance was compared with other algorithms in the literature such as neural model, reduced variable neighbourhood search, simulated annealing and other existing discrete PSO algorithms in the literature.

In the field of the metaheuristics, Chiyoshi and Galvão (2000) presented a statistical analysis of simulated annealing for the p-median problem. Elements of the vertex substitution method of Teitz and Bart combined with the general methodology of simulated annealing. The cooling schedule adopted includes the notion of temperature adjustments rather than just temperature reductions. Computational results were given for test problems ranging from 100 to 900 vertices, retrieved from *OR-Library*. Optimal solutions were found for 26 of the 40 problems and high optimum hitting rates were obtained for only 20 of them. Besides, Resende and Werneck (2004) presented a multistart hybrid heuristic that combines elements of several traditional metaheuristics to find near-optimal solutions to p-median problem. The robustness of the algorithm is demonstrated in the experimental study and better result in terms of both running time and solution quality is obtained. Senne et al. (2005) proposed a branch-and-price algorithm to solve the large scale p-median problems. The traditional column generation process was compared with a stabilized approach that combines the column generation and Lagrangean/surrogate relaxation. The combined use of Lagrangean/surrogate relaxation and subgradient optimization in a primal-dual viewpoint was found to be a good solution approach.

In more recent studies, Al-Khedhairi (2008) proposed a simulated annealing metaheuristic to find optimal or near optimal solution for the p-median problem. The proposed metaheuristic was tested on 40 well-known problems in *OR-Library* and results were reported. Berman and Drezner (2008) proposed an integer programming model and a heuristic for the p-median problem under uncertainty. The p-median problem under uncertainty is to find the location of p facilities such that the expected value of the objective function in the future is minimized. The problem was formulated on a graph and an integer programming formulation was constructed, also heuristic algorithms were suggested for its solution. Lim and Ma (2013) proposed a GPU-based parallel vertex substitution (PVS) algorithm for the p-median problem using the CUDA architecture by NVIDIA. PVS is developed based on the best profit search algorithm that shown to produce reliable solutions for the p-median problems. In this approach, each candidate solution in the entire search space is allocated to a separate thread, rather than dividing the search space into parallel subsets. Antamoshkin and Kazakovtsev (2013) studied on the p-median location problem on networks and proposed a heuristic algorithm which is based on the probability changing method (a special case of the genetic algorithm) for an approximate solution to the problem. The ideas of the algorithm are proposed under the assumption that, in the large scale networks with comparatively small edge lengths, the p-median problem has features similar to the Weber problem. The efficiency of the proposed algorithm and its combinations with the known algorithms are proved by the experiments.

The genetic algorithms are slightly used for the p-median problems in the literature. Bozkaya et al. (2002) proposed a genetic algorithm for the p-median problem and the algorithm was tested on randomly generated problems. It was shown that good results can be obtained by using this algorithm. Besides, Alp et al. (2003) proposed a new genetic algorithm that uses a greedy selection heuristic instead of the classical crossover operator. The algorithm was tested on 80 problems in the literature and compared with other heuristics. In addition, Fathali (2006) proposed a genetic algorithm for solving the p-median problem with positive and negative weights. Computational results were compared with those obtained by a variable neighborhood search method and showed that for almost all examples the proposed GA has better performance.

In the latest studies, Basti and Sevkli (2015) proposed an artificial bee colony algorithm which is a recently developed population-based optimization algorithm for the combinatorial problems. The algorithm was tested on several benchmark instances by comparing several metaheuristics in the literature and competitive results were obtained by using the algorithm. Janáček and Kvet (2016) presented a sequential approximate approach for solving the large scale p-median problem instances. It was used for the public service system design problem which is related to the p-median problem and efficiency of the proposed approach was tested on several test problems in the literature.

The summary of the p-median studies are presented in Table 1. For further investigation, Mladenovic et al. (2007) presented a survey of metaheuristic approaches for solving the classical p-median problems. In addition, Reese (2006) summarized the literature on solution methods for the uncapacitated and capacitated p-median problems and presented annotated bibliography of different solution methods.

Table 1. Summary of the p-median studies.

Study	**Method**
Rolland et al. (1996)	Tabu Search
Chiyoshi and Galvão (2000)	Simulated Annealing
Bozkaya et al. (2002)	Genetic Algorithm
Alp et al. (2003)	Genetic Algorithm
Resende and Werneck (2004)	Hybrid Metaheuristic
Senne et al. (2005)	Branch and Price Algorithm
Beltran et al. (2006)	Semi-Lagrangean relaxation
Fathali (2006)	Genetic Algorithm
Al-khedhairi (2008)	Simulated Annealing
Berman and Drezner (2008)	Integer programming and a heuristic
Avella et al. (2012)	Lagrangean relaxation based heuristic
Dzator and Dzator (2013)	Heuristic Algorithm
Lim and Ma (2013)	Parallel Vertex Substitution Algorithm
Antamoshkin and Kazakovtsev (2013)	Random Search Algorithm
Sevkli et al. (2014)	Particle Swarm Optimization
Basti and Sevkli (2015)	Artificial bee colony algorithm
Janáček and Kvet (2016)	Sequential approach

3. Proposed Genetic Algorithm

Genetic Algorithm is a metaheuristic search method that has been inspired by biological progression. Firstly, it is proposed as a problem-solving method in the 1960s. It has been intensively used as an effective and robust search method for many optimization problems ever since the 1990s. In the algorithm each solution point is represented by a chromosome. The chromosome structure will vary depending on the problem considered.

For the p-median problem, solution is obtained by assigning all demand points to the selected medians. Therefore, the chromosomes will be an array with elements as the number of median. If we have a four median problem, 14-21-10-8 could be a sample chromosome structure. Basic procedure of the proposed GA could be shown as Figure 1.

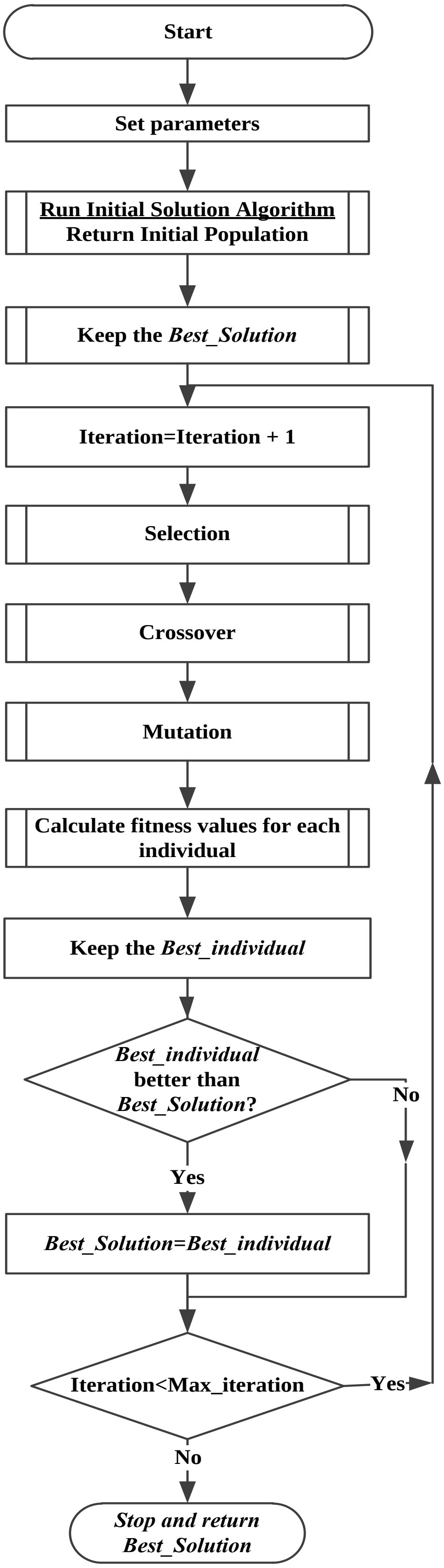

Figure 1. Basic procedure of the proposed GA.

The algorithm starts with parameters set. Thus, population size (*p_size*), mutation probability (*mp*), and maximum iteration (*max_iter*) values are determined. Later, the initial solution algorithm is run for generate high quality initial population. These procedures are described briefly as following.

Initial Solution Algorithm

The initial solution algorithm is adapted from Mulvey and Beck (1984). The pseudo code for the algorithm is shown below.

Begin
For each individual
Randomly select p-medians
Assign all demand points to nearest median
For each median
Determine the center point which has minimum distance to all demand points that assigned this median
Replace the median with center point
Calculate fitness value for the individual
End
End
Return the population
end

Fitness value calculation

Fitness value is calculated for an individual by using equation 1. In order to perform calculation, it is necessary to determine the x_{ij} values by assigning all demand points to its nearest median.

$$\min z = \sum_{i}^{n} \sum_{j}^{p} d_{ij} x_{ij} \tag{1}$$

d_{ij}: *distance between demand point i and candidate median j.*

$$x_{ij}: \begin{cases} 1, & \text{if demand point } i \text{ is served by median } j \\ 0, & \text{otherwise} \end{cases}$$

Selection

Ranking-based selection method is used for selection operator which is adapted from Correa et al. (2004). The basic idea of this method is select high quality solution more than the low quality solution. The equation 2 is used to obtain a sequence number corresponding to the random number generated. In this equation, R is the list of individuals which is ranked in an ascending order according to the fitness value. L represents the number of individuals. *Rnd* is a random number generated between 0 and 1. $\lfloor b \rfloor$ symbol used in Eq. (2) represents the largest integer which is smaller or equal to *b*. The Eq. (2) gives the sequence number (j) of the individual which will be selected from the list R.

$$Select(R) = \left\{ r_j \epsilon\, R \mid j = L - \left\lfloor \frac{-1 + \sqrt{1 + 4rnd(L^2 + L)}}{2} \right\rfloor \right\} \tag{2}$$

Crossover

In the basic structure of the genetic algorithm, a random value is generated to decide crossover. Here we perform crossover for all individual pairs but not the same ones. The number of k genes is replaced for each pair. "*k*" is generated randomly between 1 and non-identical number of genes. An example for crossover is illustrated in Figure 2. In this example, non-identical gene number is four while *k* is two.

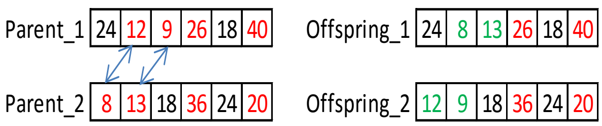

Figure 2. An example for the crossover operation.

Mutation

The mutation operator is employed by considering the mutation probability "*mp*". For each individual, a random number is generated. If the generated random number is smaller than the *mp* value, the mutation process is performed for the concerned individual. In this process, a randomly selected median is replaced with a randomly selected demand point.

4. Parameter tuning

The parameters of a heuristic or metaheuristic algorithm may have a great influence on the desired output. Moreover, the time required to the parameter setting of an algorithm sometimes far exceeds the development time (Adenso-Diaz and Laguna, 2006). Despite this fact, parameter tuning is usually neglected in most of the heuristic studies.

In this study, a statistical design of experiments (DOE) was conducted to determine the parameter levels of the proposed GA for chosen data set and thus to obtain better results. A 3^3 Full Factorial Design is performed where three levels are selected for the factors of the probability of mutation, the population size and the number of iterations. The objective (fitness) value and the CPU time are considered as response variables. Five runs are conducted for each combination of the factor levels. MANOVA and Post-hoc tests (Duncan and Tukey) are performed by using the GA solution results to identify whether the performance difference between selected parameter levels are statistically significant, for each problem set. Hence, significant parameter levels are determined and input into the algorithm. The selected parameters are presented in the Appendix A.

5. Computational Results

The proposed GA is tested on the well-known data set presented in the *OR-Library* which consist of 15 instances with up to 100 medians and 300 demand points. In addition, the results are compared with those of another GA in the literature which is presented by Alp et al. (2003).

The proposed GA was coded and implemented in Matlab® and the computational tests were made on i7-4500U CPU 2.0 Ghz personal computer. The results of the GA for the 15 test problems are presented in Table 2 and compared with the optimum values reported in the literature. Moreover, the CPU times and gap between the optimum solutions and solutions obtained by the GA are reported.

Table 2. Summary of the results for the 15 test problems of the OR-Library.

Problem	N	p	Optimum	GA		ADE		Best dev. (%)	
				Obj. val.	Time(s)	Obj. val.	Time(s)	GA	ADE
pmed1	100	5	5819	5819	0,1	5819	0,1	0,000	0,000
pmed2	100	10	4093	4093	0,9	4093	0,1	0,000	0,000
pmed3	100	10	4250	4250	0,2	4250	0,2	0,000	0,000
pmed4	100	20	3034	3034	1,2	3034	0,2	0,000	0,000
pmed5	100	33	1355	1355	3,2	1355	0,3	0,000	0,000
pmed6	200	5	7824	7824	2,6	7824	0,4	0,000	0,000
pmed7	200	10	5631	5631	3,9	5631	0,5	0,000	0,000
pmed8	200	20	4445	4445	14,2	4445	0,7	0,000	0,000
pmed9	200	40	2734	2734	30,9	2734	1,2	0,000	0,000
pmed10	200	67	1255	1255	39,6	1256	2,0	0,000	0,080
pmed11	300	5	7696	7696	27,4	7696	1,7	0,000	0,000
pmed12	300	10	6634	6634	45,8	6634	1,2	0,000	0,000
pmed13	300	30	4374	4374	75,1	4374	2,1	0,000	0,000
pmed14	300	60	2968	2968	289	2968	4,4	0,000	0,000
pmed15	300	100	1729	1731	329	1733	6,3	0,116	0,230

As shown in Table 2, optimum solutions were found in 14 out of 15 problems by using the proposed GA. Besides, the gap is about 0.12 percent for the 15th test problem. According to the CPU times, the algorithm showed promising performance. This result shows efficiency of the proposed GA with respect to both solution quality and the CPU performance. Moreover, the results are compared with those of another GA in the literature called as “ADE” which is presented by Alp et al. (2003). Computational results showed that our algorithm superior to ADE with respect to the objective values.

6. Conclusion

In this study, a new GA is developed for the uncapacitated p-median problem that uses an Initial Solution Algorithm to get better results. Thus, good beginning solutions are obtained and the computational time of the GA is reduced considerably. In addition, a 3^3 Full Factorial Design is performed where three levels are selected for the factors of the probability of mutation, the population size and the number of iterations, and parameter tuning is performed to reach a better performance. The objective values and the CPU times are considered as response variables. For each parameter level, the proposed GA was run five times. By using the GA solution results, MANOVA and Post-Hoc Tests are performed to identify whether the performance difference between selected parameter levels are statistically significant, for each problem. Hence, significant parameter levels are determined and input into the algorithm.

The proposed GA is solved for the 15 test problems presented in the *OR-Library*. The results show that the parameter tuning and the proposed Initial Solution Algorithm improved the performance of our GA. Moreover, the result showed that promising solutions can be obtained for larger problems by using this algorithm. However, the algorithm can be expanded for the capacitated p-median problem for the more practical implications.

In the future studies, the performance of the proposed GA for solving larger problems can be also examined. Besides, different heuristics or hybrid meta-heuristics can be employed for solving the uncapacitated p-median problem and compared with the proposed GA. The algorithm can be also implemented for a real case problem to show its efficiency and applicability.

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Acknowledgements

This study has been financially supported by Turkish National Science Foundation (TUBITAK), with the project number 215M143.

Appendix A. Parameter values for the test problems according to DOE.

Problem	Parameters		
	P_size	mp	max_iter
pmed1	10	0,6	20
pmed2	20	0,6	50
pmed3	20	0,3	20
pmed4	20	0,6	50
pmed5	20	0,3	150
pmed6	20	0,6	50
pmed7	20	0,3	50
pmed8	30	0,6	100
pmed9	20	0,3	150
pmed10	20	0,3	150
pmed11	20	0,6	150
pmed12	20	0,6	150
pmed13	20	0,6	150
pmed14	20	0,1	250
pmed15	40	0,3	250

Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Ergonomic Assessment of Hand Tool Design to Reduce Occupational Accidents

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Abstract

Background and Purpose: In recent years, previous researches have shown that work-related accidents occur due to the mismatch of human capabilities and the physical demand in the work environment. Effective application of ergonomics principles increases productivity, improves occupational health, and prevents possible accidents. Optimum alignment amongst man, environment and machines is achieved through ergonomic design. This study examines the impact of hand tools on industrial accidents assessment and risk reduction by using ergonomic principles.

Research method: In this study, analytical - descriptive assessment and risk management of ergonomic tool design has been conducted. The effects of tool design, before and after the intervention have been reviewed in this research. The occupational hazards to which a group of employees are exposed due to the hand tool design were assessed. Chi-square test was applied to test the data collected.

Findings and Conclusions: Before the intervention, 506 employees in the test group and 490 employees in the control group were reviewed, in which 32 and 33 accidents occurred due to use of hand tools, respectively. The following year, after the implementation of ergonomics programs, 16 cases of injury by hand tools were reported among 510 employees within the test group. Chi-square test showed that there was significant difference between accidents rates before and after the intervention; this intervention proves that application ergonomic principles reduce occupational accidents occurs in the workplaces.

Keywords

Manual task, tool design, intervention, industrial accidents, cumulative trauma disorders

Introduction

In recent years, previous researches have shown that work-related accidents occur due to the mismatch of human capabilities and the physical demand in the workplace environment. Although many studies on the musculoskeletal disorder of industrial workers have been carried out, the data about intervention on muscular injuries caused by hand tools in the industries is scarce.

Effective application of ergonomics principles increases productivity and improves occupational health and prevents possible accidents. Optimum alignment amongst man, environment and machines is achieved through ergonomic design. This research evaluates occupational accidents and ergonomic assessment and duration among persons who work in the industry.

The research was conducted in an Iranian manufacturing industry, which produces important metal parts of the Oil and Gas industries such as pipe line, tower sheet, transmission, valves and etc. Metal parts production is one of the most important Iranian industries, which comprises 3% Gross National Product (GNP) and employment (Mahdavi, 2002). In Iran nearly 1.5 million full time and part time workers are working (Sobhe, 2001) and about 7 million of people directly or indirectly depend on such industries (JSO, 1998).This study was done to understand the prevalence of musculoskeletal problems associated with hand tools design; to investigate the accidents related to tools currently use in manufacturing industry; and, if necessary, to redesign the tools with anthropometric characteristics or modify them with ergonomic principles. Thus, this study aims to evaluate the mechanism of hand tools injuries in Iranian manufacturing industry and to conduct ergonomic study of hand tools to minimize injuries

Literature Review

In a large number of industrial occupations, hand tools are the primary devices. A major concern of these industries is the high percentage of injuries that occur annually (Lewis and Narayan, 1993). Upper extremity cumulative trauma disorders (CTDs) have been associated with work activity in a variety of tasks. Awkward postures were recognized as key ergonomic risk factors for CTDs in the literature (Armstrong et al., 1986; Muggleton et al.,; 1999' Putz-Anderson, 1988). Schoenmarklin et al. (1994) confirmed the view that flexion and extension might cause hand problems. Musculoskeletal disorders (MSDs) are a leading cause of occupational injury and disability in the developed and industrially developing countries (Shahnavaz H. 1987). The economic loss due to those disorders affects not only the individual but also the organization and the society as a whole (Kemmlert K. 1994).

At present, MSDs are one of the most important problems ergonomists encounter in the workplace all over the world. In many countries, prevention of work-related musculoskeletal disorders (WMSDs) has become a national priority (Choobineh 2004). WMSDs are a worldwide concern. They are present among both Industrialized Countries (ICs) and Industrially Developing Countries (IDCs). In IDCs, the problems of workplace injuries are extremely serious (Shahnavaz H. 1987). Poor working conditions and the absence of effective work injury prevention programs in IDCs have resulted in a very high rate of MSDs (Jafry O'Neill DH. 2003). According to the Bureau of Labor America (BLA) in 2012, 34% of all injuries and illnesses that resulted in days lost were related to MSDs (Bureau of Labor, BoL2013). Also according to Washington State workers compensation, in 2013, 24% of the compensation paid to workers because of MSDs (Wuellner, 2014). Then lost work days due to musculoskeletal disorders in America can be considered one third lost work days of the country (Maloney SM, 2014).

In addition to awkward posture, repetition movement, and forceful exertion, vibration is another risk factor for MSDs (Gauthier et al., 2012).In many occupations, some of the major causes of work-related disorders and diseases are linked to the use of hand tools. It has been shown that tool design may play an important role in the development of work-related problems in the upper limbs (Lewis and Narayan, 1993; Kadefors et al., 1993). Occupational accidents can be linked directly to the use of specific hand tools as well (Choobineh et al., 2004a). Researchers believe that repetitive work performed with a powered hand tool (Gooyers & Stevenson, 2012). The relationship between occupational musculoskeletal disorders (MSDs) and the use of hand tools is well known (Aghazadeh and Mital, 1987; Armstrong et al., 1982). Poor design of hand tools may result in cumulative trauma disorders (Armstrong, 1986). Ergonomically well-designed hand tools may reduce the risk of occupational injuries of the upper limbs. They also provide comfortable work for the users and give high product quality to the consumers (Sparling et al., 1993).

Cumulative trauma disorder (CTD) arises from repetitive motions and actions (Siegel, 2007). The repetitive grasping and manipulating of controls which cause problems, or operation of the controls that require high manual force are the foremost carpal tunnel syndrome (CTD) risk factors among the musculoskeletal injuries (Warren & Sanders, 2004). The cause of more than half of all absences in the workplace are musculoskeletal disorders and back pain. It means that musculoskeletal diseases as the second most common cause of absence from work is recognized. Hand tools on their own with only 6.1% of injuries and illnesses, play major role absences in their work (On average four days of work absence) (Cacha 1999). Repetitive motion and force exertion to hand tools develop upper extremity musculoskeletal injuries (Gooyers & Stevenson, 2012).

As the use of hand tools may play an important role in the development of disorders and accidents (Choobineh 2007), it is obvious that ergonomic improvements in the design of hand tools are essential for promoting professional users' health, particularly where there is intensive exposure (Motamedzade 2007).

Methodology

This study was conducted from January 2014 to September 2015 among workers of one of the manufacturing industry company in Iran. A total of 996 male workers were employed on the production line of the factory, for the next year in 2015, this number has been increased to 1007 workers. They worked in three shifts and in three groups as 15 different units with using varieties of hand tools (e.g. pliers, hammers, screwdrivers and).

In this study, during the first year, all medical records, accident, incident and near miss reports has been checked in order to find out the number of workers who have musculoskeletal problems such as CTD. Workers with background diseases or occupational or non-occupational accidents affecting the musculoskeletal system were excluded from the study. By the end of 2014, all musculoskeletal discomforts were collected via medical reports and anonymous questionnaires. The questionnaire consists of two parts and covered following items; the first part includes the demographic characteristics such as gender, age, height, weight, job tenure, education, health, and medical background. In the second part, Nordic Musculoskeletal Questionnaire (NMQ) for wrist and hand was utilized for medical examinations (Kuorinka et al., 1987). The workers were asked whether they had experienced pain in the wrist or/and hand more than 1 day during the previous 12 month.
Reported MSD symptoms were limited during the study to the past two years. All units were visited and the questionnaires were completed by interviewing the workers. This questionnaire has been widely used to investigate MSDs in many Iranian industries and health research, for instance rubber industry (Choobineh et al., 2007a), telecommunication industry (Choobineh et al., 2007b), petrochemical industries (Choobineh et al., 2007c) and among surgical technicians (Movahedet.al. 2007).

Three program changes were done for next period of study in order to understand the effect of musculoskeletal problems on worker's physical health; (1) replacement of non-ergonomic tools with standard sample, (2) training workers on how to use ergonomic tools, and (3) training workers on the hazards of workplace specially related to hand tools. For this purpose, the workers were divided in two groups; a control and a test group. The total number of investigated employees before and after the intervention for two groups during the period of study is shown in table 1. The first group was the test group and second one was the control group. The intervention was done only for first group of worker in 2015.

Table 1.Test and control group data; before and after intervention

	First group of workers (test group)			Second group of workers (control group)		
Year	No. healthy workers	No. affected workers	Total	No. healthy workers	No. affected workers	Total
2014	474	32	506	457	33	490
2015	494	16	510	466	31	497

At the end of the study, the documents (including all medical records, accident, incident and near miss reports) were checked again. Chi-square test was used to explore association between demographic and work-related variables and reported musculoskeletal symptoms.

1) Replacement of non-ergonomic tools with new design:

Hand tools may play an important role in the development of disorders and accidents. World Health Organization (WHO) reported that 6.1% of all injuries in industries associated with hand tools and these injuries resulted in an average of four days of loss work (WHO, 2007). At the end of the first period, our findings were in parallel with those of WHO. In order to reduce it, WHO (2007) suggested to investigate the design of hand tools and then if necessary, redesign the tools based on anthropometric characteristics and ergonomics principles. At beginning of 2015 all non-ergonomic tools were replaced with new design, and these new tools were used during the second period.

Before intervention	After intervention
	
This hammer was used for bending metal parts	Ergonomic Hammer(Model Mega Tools M85216)

Figure1: Hammer, Left side: Old design, Right side: Ergonomic design

As shown in Figure 1, a non-slip texture has been used to improve grips by increasing the friction between the hand and the handle. In head part of hammer for ergonomic model, it is fixed by factory process not by using welding spots.

Before intervention	After intervention
	
This hammer was used for straightening metal parts	Ergonomic Hammer (Model NTH-2515Tools)

Figure 2: Hammer, Left side: Old design, Right side: Ergonomic design

Figure-2 shows that, using non-slip handle and metal body in new design instead of using wood body and slip handle in old model.

Before intervention	After intervention
	
Mallet	Ergonomic Mallet (Model Potk Sledge)

Figure 3: Mallet, Left side: Old design, Right side: Ergonomic design

Figure 3 illustrates that in the new model, the tool handle has been oriented in such a way that while working, the hand and the forearm were aligned and no significant deviation from neutral posture occurred as contrast to previous samples.

Before intervention	After intervention
	
Screwdriver	Ergonomic Screwdriver and Philips screwdriver (Model Mega Tools M33144)
	
Screwdriver	Ergonomic Screwdriver (Model Mega Tools M85216)

Figure 4: Screwdriver, Left side: Old design, Right side: Ergonomic design

Using ergonomic pad for handle of screwdrivers is shown in Figure-4. In order to avoid contact stress in the palm, the tip and the base part of the handle in ergonomic model had soft features and were extended out of the closed hand.

Before intervention	After intervention
	
Wire cutter	Ergonomic Wire cutter (Model Nova NTP-8010)
	
Plier	Ergonomic Plier (Model Mega Tools M85216)

Figure 5: Wire cutter and Plier, Left side: Old design, Right side: Ergonomic design

As shown in Figure-5; an appropriate texture was used to prevent slip and contact stress on the hand and fingers. The tool handle was oriented such that during work the wrist was kept in healthy posture and no significant deviation from the neutral posture occurred. The rounded end of the handle was extended out of the closed hand, which caused stress reduction on the palm.

Before intervention	After intervention
	
Spanner	Ratchet Handle spanner (Model NTS 7006)

Figure 6: Spanner, Left side: Old design, Right side: Ergonomic design

Spanner as shown in Figure-6 is one of the most important tools for the workers. Many workers complained of blisters on their hands while using such an old design. In new model, it has been used a bumper on handle of spanner to prevent blisters.

Before intervention	After intervention
	
Monkey wrench	Ergonomic Monkey wrench (Model DB 1810)

Figure 7: Monkey wrench, Left side: Old design, Right side: Ergonomic design

The new model of monkey wrench has a design without sharp edges or finger grooves on the handle. Because of high force was applied on the handle, the new model prevented contact stress by reducing pressure on the nerves and blood vessels.

2) Training on how to use ergonomic tools

After replacing the old tools with the new ones, all workers according to schedule were trained for one month to understand how to use ergonomic tools correctly. For instance, they learnt about awkward posture, advantages of ergonomic tools and adverse effects of using non-ergonomic tools (e.g. some accidents related to hand tools were presented).

3) Training workers on understand the hazards in the workplace

During the second period, the test group participated in 2-hour health and safety classes per week. In order to improve their knowledge about hazards in the workplace, they took training on labor law, risk assessment, all types of incidents, accidents, near miss cases and emergency response plan. Instructors were selected with high experience in industries. Also varieties of learning programs were used in their teaching methods which were based on Occupational Safety & Health Administration (OSHA) guidelines and American Conference of

Governmental Industrial Hygienists (ACGIH) recommended publications. In each class, the learning level among the audience was measured by questionnaires applied at the beginning and at the end of the class.

Results

In 2014; 996 employees, and later in 2015; 1007 employees participated in the questionnaire. Table 2 shows the demographics and work-related characteristics of the respondents.

Table 2.Individual data and demographics of the employees participated in the study for both years.

		***n*=996 (2014)**	***n*=1007 (2015)**
Gender (%)	Female	0	0
	Male	100	100
Age (years)	M (SD)	37.01 (6.24)	38.09 (6.08)
	Range	23-59	23-60
Weight (Kg)	M (SD)	76.49 (10.01)	78.49 (10.11)
	Range	49-114	49-118
Height (cm)	M (SD)	170.39 (6.51)	174.18 (6.76)
	Range	145-198	145-198
Body Mass Index	M (SD)	25.2 (2.99)	25.5 (3.12)
	Range	15.51-35.43	15.58-35.
Job tenure (years)	M (SD)	9.42 (4.48)	10.28 (4.48)
	Range	1-29	1-30
Education (%)	High school degree	69.7	68.4
	Associate's degree [a]	13.9	14.0
	B.Sc	14.9	14.8
	M.Sc	1.5	2.8
Smoking (%)	Yes	28.2	36
	No	71.8	64
Exercise (%)	Occasionally	72.8	75
	Regularly	11	11
	No	16.2	14
Working Schedule (%)	Shift	58.4	61.1
	Day working	41.6	38.9
Type of job(%)	Office	13.9	16.1
	Operation	63.9	62.3
	Both [b]	22.4	21.6

[a] One that is given after completing two years of study at a junior college.

[b] Employees performing in both office and operation activities.

The results of the questionnaire showed that musculoskeletal symptoms in wrist/hands were common among workers. Table 3 presents the prevalence of symptoms in wrist and hand regions of the participants during the last two years of period.

Table 3.Frequency of reported symptoms in Wrist and Hand regions during the study

Body Region	Job Type (n=996 in 2014)			Job Type (n=1007 in 2015)		
	Office (%)	Operation (%)	Both[a] (%)	Office (%)	Operation (%)	Both[a] (%)
Right Wrist and Hand	25	26	24.1	18	21	19.1
Left Wrist and Hand	24	23.4	24.8	19.8	20.1	18.4
Both **[b]**	16.1	17.6	18.1	14.2	15.4	12.4

a Employees working in both office and operation activities.

b Employees using both wrist and hand.

Table 4 compares point prevalence of the symptoms among the employees studied, general Iranian population (National Research Center of Medical Sciences of Iran, 2011), Statistical analysis (test of proportion) revealed that the differences between the prevalence rates of symptoms in Wrists/Hands among the employees studied and the general Iranian population were significant ($P<0.0001$) for both period of study. In 2015, there was 4.5% decrease in symptoms due to ergonomic intervention.

Table 4. Comparison of point prevalence of musculoskeletal symptoms in Wrist/Hand in the employees studied and general Iranian population

Body Region	Employees studied in 2014 (age=23-59)	Employees studied in 2015 (age=23-60)	General Iranian population [a] (age=15–69)
Wrist/Hand	22.1%	17.6 %	8.1%

[a] National Research Center of Medical Sciences of Iran, 2011

In order to find out effect of changes, statistical tests were conducted. Chi-square was selected for this purpose. Not only was the frequency of occurrence in a particular class (observed values) considered, but also the frequency that of the class (expected value) was also considered. . According to this test, like other inferential statistical methods, it should be declared whether the frequency of observed and expected frequencies is significantly different or if this subtle difference is the result of chance. In fact, Chi-square test has showed there is a connection between two variables or two variables are independent of each other.

First step is to acquire Chi-square result for the first group of workers (test group) is shown in Table 2.

Table 5.Test group results (before and after intervention)

	Healthy	Affected	Total sum
Year 2014	474 (A)	32 (B)	506 (A+B)
Year 2015	494 (C)	16 (D)	510 (C+D)
Total sum	968 (A+C)	48 (B+D)	1016 (N)
	BC=32*494=15808	AD= 474*16=7584	

For the test group, it is shown that there are significant differences in two years and this reflects positive effect intervention.

$$X^2 = \frac{1016.\left(7584 - 15808 - \frac{1016}{2}\right)^2}{(506).(510).(48).(968)}$$

$\chi^2 = 5.04 > \chi^2_{0.05} = 3.841$ Which shows positive effect of intervention

The second step is to conduct Chi-square test for the control group. According to calculations shown in Table 6, no significant difference occurred control group over the past two years.

Table 6.Control group results (before and after intervention)

	Healthy	Affected	Total sum
Year 2014	457 (A)	33 (B)	490 (A+B)
Year 2015	466 (C)	31 (D)	497 (C+D)
Total sum	923 (A+C)	64 (B+D)	987 (N)
	BC=13*466=15378	AD= 457*31=14267	

$$X^2 = \frac{N.\left(AD - BC - \frac{N}{2}\right)^2}{(A+B).(A+C).(C+D).(B+D)}$$

$$X^2 = \frac{987.\left(14167 - 15378 - \frac{978}{2}\right)^2}{(490).(497).(923).(64)}$$

$X^2 = 0.035 < \chi^2_{0.05} = 3.841$

Thus, it is found that there is no significant difference between two periods of the study (i.e. 2014 and 2015) within the control group.

Discussion

This study showed that high proportion of workers had experienced wrist/hand symptoms during the course of the study (Table 5). Previous literature showed that, these problems can be reduced by using proper hand tool design (Aghazadeh and Mital, 1987; Armstrong et al., 1982; Armstrong, 1986; Sperling et al., 1993; Lewis and Narayan, 1993; Kadefors et al., 1993).Similar to all hand tools, the purpose of the handle usage in the manufacturing industry is to facilitate the transmission of force from the workers' musculoskeletal system to the tool. In order to optimize force transmission, it is necessary to optimize handle design (Pheasant, 2006). Therefore, in this study the new designs were considered for safe, comfortable and easy use of the hand tools. This implies that intervention programs for preventing or reducing MSD problems by hand tools among workers should focus on reducing physical exposure to the MSD risk factors of wrist/hand. Poorly designed traditional hand tools are commonly used in manufacturing operations. It seems that these traditional hand tools greatly need redesigning. The results of the ergonomic redesign indicated that the ergonomic handles were comfortable and preferable for the workers. No soreness was reported in the palm of hands by the participants while working with the new tools. During work with the new tools, the wrist was in appropriate posture (in accordance to NIOSH recommendation 2004: Select a tool that feels comfortable with a handle diameter in the range of 1 1/4 inches to 2 inches).

Comparisons revealed that the differences between the prevalence rates of symptoms in writs and hands between the employees under study and the Iranian population were significant. This may indicate that jobs in manufacturing industries can be considered as occupations with risk of developing musculoskeletal symptoms in the wrist/hand.

Due to the cross-sectional design of the study and data collection the findings of this study should be interpreted with caution. In this study, however, by limiting the recall period for reported symptoms to the past 12 months, the time over which data needed to be recalled was restricted. Finally, since the analysis was limited to workers who are currently working, and workers who had left jobs due to musculoskeletal symptoms may have been excluded from the study, which can lead to healthy worker effect. Thus, the data may underestimate reported symptoms and the association of perceived demands with musculoskeletal symptoms.

For a further study, it could be possible to find out the association between hands/wrists symptoms and individual factors. Some researchers have found positive association between smoking and musculoskeletal symptoms (Brage, 1996; Ljiljana et al., 2004), but there are a few studies about other individual factors. Moreover, it could be so important to understand the relation between manufacturing industries and other type of industries such as Oil and Gas, Cars factory and etc. It needs to be done the same method in order to find out which industry has high risk.

Conclusion

This study showed that poor working conditions and musculoskeletal problems among company workers accrued in high rate. Thus improvement of working conditions and taking corrective invention to reduce the risk level into consideration seemed essential. Present observations depicted that the ergonomic problems in hand/wrist region in this industry oriented from awkward posture by using hand tools. It is, therefore recommended that any interventional ergonomic program in the workplace should focus on eliminating awkward postures and improper hand tools.

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Biography

Orhan Korhan is an Associate Professor of Industrial Engineering at the Eastern Mediterranean University. He graduated with a BS from Eastern Mediterranean University in 2000, a MS from the University of Lousiville in 2002, and a PhD from Eastern Mediterranean University in Industrial Engineering in 2010. His current research interests include Work-related Musculoskeletal Disorders, Educational Ergonomics, Human Computer Interaction, and Facilities Planning and Design.

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An estimation of anthropometric measures of adult male population of Anatolia

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Abstract

Objective: This study aimed to estimate 65 static and dynamic anthropometric dimensions of adult male population of Anatolia.
Background: Anthropometric dimensions vary across world populations. Hence, it is a need to determine these dimensions for each specific groups of people for various design purposes such as consumer products, equipment, machinery, clothes, furniture, workstations and living places to fit the users. Although there are a number of studies on the anthropometry of population of Turkey, most of them lack in various aspects to establish a valid and usable anthropometry database for the population of Turkey.
Method: For the purpose, 65 static and dynamic body dimensions were taken from 250 adult males ages from 18 to 70 yrs using a grid-board and an anthropometric kit. Sampling is done in a stratified manner including subjects from seven regions of Turkey with varying age groups and occupations. The required sample size was determined through a pilot study.
Results: Sixty five body measures of adult male population of Anatolia were statistically determined. Average stature and weight were found as 171.5 cm and 76.6 kg, respectively. A comparison with 1980s male data indicates that, on average, stature increased 3 cm and weight increased 8 kg. The comparison results with other nationalities indicate that anthropometric data of the male population of Turkey, in general, is similar to the some Southern Europeans and Americans in the USA, greater than Southern Asians and lower than Northern Europeans.
Conclusion: Considering the anthropometric differences among world populations, the designers should take the anthropometric dimensions of the target population into account; in this case, the male population of Anatolia.
Application: The findings can be used for designs requiring anthropometric data of Anatolian male population.

Keywords: anthropometry, anthropometric dimension, Turkish male, ergonomic design

Acknowledgments
This research was supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK) Grant 112M936 awarded to Mahmut Ekşioğlu.

Biography
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An effective heuristic policy for a recoverable manufacturing system with substitutable products

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Due to economic benefits of product recovery and also environmental regulations and concerns, many manufacturers incorporate product recovery activities into their manufacturing systems where a significant portion of production uses recovered material. The resulting production system is known as *recoverable manufacturing system* or *hybrid manufacturing/remanufacturing system*.

We consider the inventory control for a periodically-reviewed hybrid manufacturing/remanufacturing system with downward product substitution in a stochastic demand and return setting. The two products of the system, referred as remanufactured and manufactured items, have different costs and selling prices as well as different demand streams. The remanufacturing capacity is limited by the amount of returns available which is typically not under the control of the manufacturer. Therefore, the stock-out risk for remanufactured items is higher than that of the manufactured item. Stock-outs of remanufactured products can be mitigated with a substitution strategy where unmet remanufactured product demand is satisfied using new products. The optimal inventory policy for this system can be determined by formulating the problem as a Markov Decision Process (MDP) [1]. However, an MDP's solution is not a closed-form policy, rather it is a list of optimal production decisions for every system state. This list does not provide direct insight into the structure of the optimal policy and it is not practical to use in real systems. Inderfurth [2] showed that the optimal policy has a complex structure even for the single period version of the problem. The aim of our study is to develop an easy-to-implement heuristic policy that can control this system near-optimally.

We first formulate the problem as a MDP and based on a characterization of the optimal control we develop the proposed heuristic policy. Then, we design a neighborhood search algorithm to determine the values of the control parameters for the proposed policy. We compare the performance of this policy to the optimal inventory policy as well as the commonly used in practice base-stock policy through a real case study involving an automobile spare part manufacturer. We also evaluate the performance of the search algorithm. The results show that the search algorithm can find the optimal values for the policy parameters, and the proposed heuristic policy is near-optimal (the maximum error is 0.6% from optimal) and also performs better than the base-stock policy.

In conclusion, the proposed policy provides manufacturers an effective means of controlling the manufactured and remanufactured product inventories under substitution.

Acknowledgements

This work has been financially supported by the Center for Additive Manufacturing and Logistics at N.C. State University.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

GSCM for Construction Waste Management in Green Building Operations

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Abstract

Green buildings also known as green construction or sustainable building are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. Today the environmental issues and the concern for sustainability is encouraging more effective and efficient usage of energy, water and material currently used, ensure the prevention of any kind of waste, perform environmentally sensible and eco-friendly building design and be environmentally friendly in the process of construction. Environmental problems and the growth of construction industry cause a new topic to manage construction waste with the help of green supply chain management (GSCM). This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages. GSCM reduces energy usage and waste, so it prevents any problem that will occur in human health and environment. This paper aims to combine the architects green building operations together with the engineers green supply chain management for both reducing the usage of materials, encouraging more effective and efficient usage of energy, water and material currently used, ensure the prevention of any kind of waste, perform environmentally sensible and eco-friendly building design and to be able to reuse, recycle, or recover the waste. The European Union Council published a waste management directive in 2008 that gives some goal numbers to manage construction waste to minimize the environmental effect. The goal is to reach a reduction of 70% of construction and demolition waste (CDW) that will be reused, recycled or recovered in 2020. The aim of this paper is to explore the cost-benefit and social-benefit reflections by the combination of these two techniques, based on the literature review and case study examples from Turkey a model is built and propositions regarding Green Building operations using GSCM and reverse logistics are formulated.

Keywords

Green supply chain management, construction waste management, green building design, green building operations

1. Introduction

Today growing industries are causing pollution that affect our lives directly. It gives harm to our health and is a big threat for the next generation. In this case green products and services are becoming more popular. Production systems are being customer focused to meet their requirements on time, with high quality. Even in construction industry, it is important to manage every step, beginning with the building design to the demolition. Not just the aesthetics or the usage of the building is considered but also resource efficiency has to be reached. As a solution, green building design is a way to reduce usage of raw materials at the beginning and to use high percentage of recyclable materials to make sustainable structures. When the design phase is considered, only architectures and civil engineers will have role to make the building "green". But as a whole construction industry, suppliers and other subcontractors are also in the whole supply chain. For this reason, to make the whole production line sustainable, green supply chain models will be useful to connect every step to each other with every kind of actors in the supply chain.

As a new topic, GSCM makes sustainable systems with the help of waste management directives. Both European Union and Turkey published regulations to manage construction and demolition waste. First aim is to reduce the raw material in the source and if it cannot be reduced, than the second aim is to recover those materials as much as it can be. To be able to reduce the raw material such as the materials that are directly used in the structure, water and energy resources it can be designed as green building at the beginning. It is possible to take green building certification with the required properties that will be given more detailed in the following sections.

This paper is the further study of a master thesis which is only comparing the CWM, within GSCM, between EU countries and Turkey. Current supply chain models will be defined and then a new model will be developed to see the integration of green building design operations to GSCM will be effective to provide sustainability.

2. Literature review

2.1 Green Supply Chain Management (GSCM)

Supply chain management definition changes day by day according to its broadening scope [1]. SCM includes logistics and trade while operating both customers and suppliers [2]. Supply chain is a cycle that starts from suppliers and ends at customers as the product or service flow [3]. Another definition is that supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer [4].

Supply chain traditionally starts from the cradle to the grave, which means from raw material state till the end product reaching the customer. However today environmental issues force processes to change and comes up with new operations such as recovery options. For this reason, closed loop supply chain, a new definition, allows the finished good collected from customers which are end-of-life products now, and go in to some other processes for recovering them [5]. The aim of the end-of-life recovery options are to recover material, energy and avoid landfill. This recovery is a value that if it is managed properly, high profits will be gain for both producers and customers [6].

Today companies are aware of their responsibilities about the environment depending on regulations. This leads to sustainable systems that will continue their processes without giving any harm to the environment. Environmental issues are seen at every step of supply chain that starts from getting the raw material and ends with reuse or recycle or disposal [7]. This causes a requirement for companies to have a green supply chain management (GSCM). A study in India, found that there are different pressures for different sectors to be able to adopt GSCM in their own traditional supply chains [8]. To integrate GSCM to a company five different applications can be used as environmental management systems, green purchasing and design, investment recovery and strong relations with customers [7]. In common green activities and sustainability have an intersection in practice which is 4R: reduction, redesign, reuse and remanufacture [2].

2.2 Construction Waste Management

Constructions cause air, water and noise pollution and today with global warming environmental issues became very important. Even in construction design, green materials are being preferred to minimize waste and construction firms are starting to use green supply chain management to make their work sustainable. Green buildings, sustainable design and constructions, construction waste management are some of the sustainability topics that are being used by producers [9]. The best way to minimize the construction waste generation is to disposal. Also material types have to be selected very carefully to get rid of recycling limitations that means recycable materials should be preferred [10].

With different stages in construction, it is possible to define and measure construction and demolition waste. In the first half of the life cycle CDW type can be defined. The first half is where the concept and the design phase including selecting suitable materials for the construction. However, in the second half of the life cycle the CDW amount is measured. This amount can be gathered from the data which is already processed as a construction project and the material used in the building can be measured. Also at the end, in demolition stage, materials can be clearly seen after decomposition.

To leave a healthy environment with high level of social, economic and environmental conditions to future generations, sustainability is important which leads to improved quality of systems [11]. Supply chain management has four specific roles in construction; improving the interface between site activities and the supply chain, improving the supply chain, transferring activities from the site to the supply chain, integration of site and supply chain. SCM helps to understand construction problems and shows a direction to solve them but practical methods for SCM should be improved to implement for specific situation of construction [12].

2.3 Green Building Design

CWM is not the only way to reduce pollution and other bad effects occurring at the environment. Like any other industries, green production is very popular today at construction sites. At the design phase, architectures are considering different types of shapes and materials to provide energy saving. Green building design provides savings in different scopes: nearly 30% energy, 35% carbon, 30-50% water usage, 50-90% waste cost savings will be reached [13]. Figure 1 is taken from “World Green Building Trends Smart Market Report” which was published at 2013, shows the importance of the reason for building green structures according to different locations.

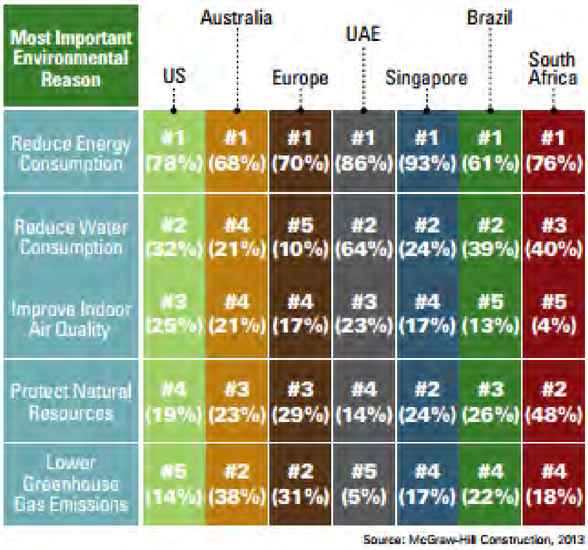

Figure 1: Most important environmental reason for building green by locations.

There are different definitions of green building in literature. A green building is better designed than a traditional building in case of its effect to the environment. Another definition is the building that provides an important development and innovation within its environment. Green building is not only the consumer but also a manufacturer of energy and water. During its life cycle, it presents the most healthy environment while using water, energy and land sources efficiently [14].

3. Analysis of CWM in Turkey and European Union Countries

3.1 Waste management principles related to Turkish and EU Council directives

Regulations about common waste management at Turkey, are improved according to waste variation. EU directives and country based guidelines are published and put into practice. In this scope, different types of waste are being stored regularly such as domestic solid waste, excavation soil, construction and demolition waste, waste batteries and accumulators, hazardous waste, herbal waste oils, medical waste, end-of-life tires, packaging waste, polychlorinated biphenyl and polychlorinated terphenyl, waste electrical and electronic equipment, waste oil, end-of-life vehicles, maintenance and repairment equipment of vehicles [15].

One of the most important principles of Turkey's waste management strategy is to prevent waste at source, otherwise reduce waste and finally if waste is unavoidable recycle it. Collecting all terms related to waste management directive under a common structure, simplifying regulations and adjusting them according to the EU waste management directive updates are being maintained by Ministry of Environment and Urban Planning.

There are two issues on recycling in the 10th development plan for years 2014-2018:

- Industries will give attention to applications such as recycling and recovery.

- Recycling performance is negatively affected by some topics such as lack of knowledge about recycling benefits which is one of the important issues in the solid waste management, lack of standardization of the recovered secondary products, deficiency of incentives and orientation system.

According to the national data about recycling; at 2003, at 46 recovery centers nearly 4 thousand people were employed and as a result of recovery operations 62 million TL added value provided. At 2011, at 898 recovery facility nearly 60 thousand people were employed and as a result of recovery operations the provided added value exceeded 1 billion TL [15].

"Regulation on Excavation Soil, Construction and Ruin Waste Control" is law in force that was promulgated at 18.03.2004. Following goals are given in the regulation: Reduce excavation, construction and ruin waste without giving harm to the environment at the place where they are produced, collect, store temporarily, transport, recover, use and dispose them.

Firstly to reduce excavation soil and construction/demolition waste at source, reuse, collecting separately, recovery and especially evaluating as infrastructure material are essentials. Also not mixing excavation soil and construction/demolition waste is essential. To make a good system for recycling and removing is important by separating waste at the source and making "selective destruction".

Recovered products, with respect to the standards, are used with original materials or separately at new concrete production, road, parking lot, pavement, walking roads, drainage works, sewer pipe and as filling material at cable laying, lower and upper building construction, sports and game centers construction and other filling and recreation works primarily. Construction / demolition waste which cannot be recovered are used as daily covering material in storage areas after required separation and sizing.

Permitting authority is given to the city and district municipalities in the urban area, metropolitan municipalities in metropolitans and district municipalities for which cities are not metropolis [15].

Waste generation is increasing day by day at many countries due to the growth of towns and cities. Many regulations about construction and demolition waste management are developed to prevent the environment [16]. Directive 2008/98/EC starts with waste, recycling and recovery definitions. It also explains how waste can be classified to be a secondary material or product. The aim of the waste management is protecting the environment without giving harm to human health, animals or plants, water, air and soil.

Construction and demolition waste (CDW) is nearly 30% of total waste which is generated in European Union. CDW includes many kind of recycable material such as excavation soil, metals, asbestos, plastics and so on [17]. Directive 2008/98/EC gives a strict goal for construction and demolition waste that by 2020, 70% of construction weight has to be recovered. Size or type of the construction do not change this goal that every project must reach it in 5 years. It seems to be strict but it is very important to manage those CDW to protect human health and the environment.

In terms of waste management European Union has published a directive (2008/98/EC) which gives details about goals for EU countries according to different types of waste. After giving the definition of waste, to standardize waste management at EU countries, the directive mentions the objectives as follows:

"In order to comply with the objectives of this Directive, and move towards a European recycling society with a high level of resource efficiency, Member States shall take the necessary measures designed to achieve the following targets:

(a) by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight;

(b) by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight." [18].

Turkey is not a member of EU but as a candidate ministries are trying to edit regulations according to the EU standards. In 2008, ministry of environment and forestry published a waste management action plan that includes

4 years for each cities in Turkey. It stated goals for cities to manage solid and hazardous waste types in order to protect environment and human health.
There is no goal like gaining 70% of materials with recycling at 2020 which is mentioned in the EU Directive, for Turkey in the related regulation. At Turkey, every year 125 million tons excavation soil is evaluated to regain. At the current situation construction and demolition waste amount is nearly 4-5 million tons per year. With the new regulation of rehabilitation of areas that are under risk of disasters for the first 3 years, annual goal will be 40% that is 10 million tons/year and 6 million tons/year for regaining materials [15].

3.2 Current supply chain models

Istanbul Metropolitan Municipality Directorate of Environmental Protection manages construction and demolition waste according to the Turkish regulation. First of all, contractor defines the waste amount of the construction or demolition and applies to the district municipality with a 70 TL valued receipt to get acceptance form while showing the construction/demolition license. This form must be filled by the contractor who is the producer of the construction (or demolition), transporter (logistics firm) and storage firm. Trucks that will carry CDW must register to the “Vehicle Tracking System (VTS)” and the firm must get the transportation license. VTS is not included in the regulation but it is active according to the act of the parliament. Only vehicles which are registered to the VTS can get the transportation license from Istanbul Metropolitan Municipality Directorate of Environmental Protection. Trucks which have lift system will be registered to the VTS and they have to be yellow, on their sides there cannot be any kind of symbols and also the license plate and “excavation soil and construction and demolition waste transporter” must be written on both sides of the truck. In the regulation, it mentions about containers that will be in front of the construction (or demolition) site but in practice there are dumper trucks instead of containers for waste.
Today construction firms in Turkey usually use subcontractors to transport CDW to storage areas. They have to take permission from municipalities to send their waste to the pre-defined areas according to the capacity of the landfill. In Istanbul, ISTAC is the only company that manages landfills and recycling operations in construction industry. ISTAC is an affiliate of Istanbul Metropolitan Municipality, which works according to the national and international standards [16].

Figure 2 shows current supply chain model for a construction firm in Turkey. In this model firm sends CDW to the land fill and the process finishes. This means that firm does not get any profit from their own waste and those waste may give harm to the environment if they are stored at a landfill.

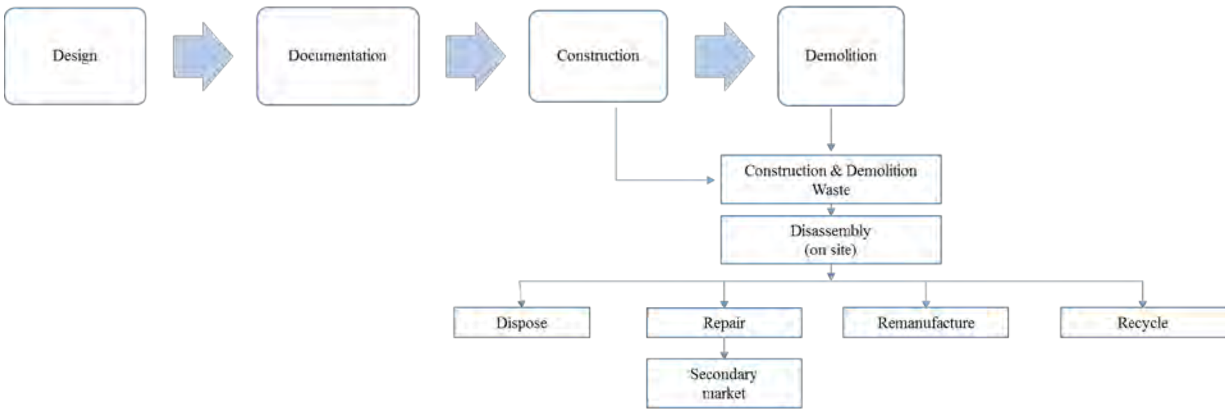

Figure 2: Current Supply Chain Model for a Construction firm in Turkey.

Annual construction and demolition waste amount is given at Table 1 that is taken from Istanbul Metropolitan Municipality Directorate of Environmental Protection [17].

Table 1: Annual excavation soil and CDW amounts that are disposed or recovered, and administrative sanctions.

	Unit	2010	2011	2012	2013	2014	Total
Disposed excavation soil amount	Thousand tons	24.100	47.709	52.455	65.502	69.999	259.765
Disposed CDW amount	Tons	5.361	5.680	5.152	0	0	20.451
Recovered excavation soil amount	Thousand tons	34	36	284	280	221	855
Recovered CDW amount	Tons	73.200	116.952	15.695	14.312	0	220.159
Administrative sanction	Piece	1.482	887	716	439	320	3.844
	Million TL	55	45	29	30	26	185

It is difficult to manage construction and demolition waste in EU because of strict goals which is mentioned before. A study showed that Southern Europe countries need development in their measures, and Central and Northern countries need new models to integrate waste management technologies locally, so that waste management systems will work efficiently to be able to reach those governmental goals [18]. Construction and demolition waste management regulation was published in Spain and it was tested in the Seville area. In Figure 3, the closed loop system can be seen that is known as Alcores model for waste management. This system allows construction and demolition waste to be checked and operated and also recycled [17].

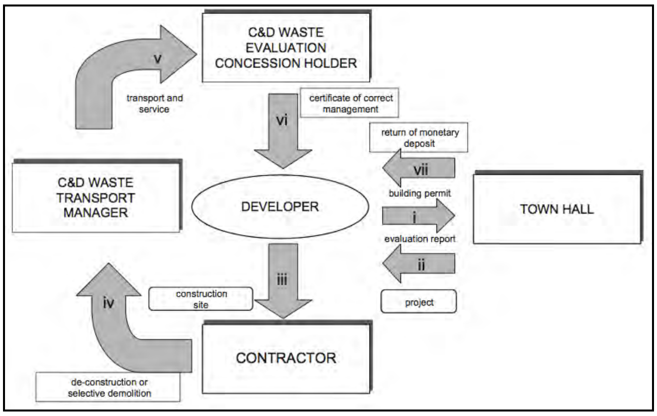

Figure 3: Construction and demolition waste management model used in Spain.

This example shows a great auto-control for a firm in Spain. They operate every supply chain management steps, and after transportation they again check the validity if the management tools are used properly or not.

4. Discussion

4.1 Integrating green building design to GSCM

To reach the waste management goals with using GSCM starts with the reduction of the raw material that is thought to be used in the structure body. It is hard to make the balance between the strength and the amount of the material at the design phase according to different material types. It is possible to use "green" materials while reducing the amount and make the structure as strong as it was with the traditional materials. There are new type of materials that can be use as substitutes. With the advantage of being light and durable, they are also recyclable so that can be connected to GSCM. If a closed loop is designed to make the system sustainable, manufacturer will be able to use waste materials in the other construction projects as second quality materials. To reach regulation goals both in Turkey and EU, waste amount has to be reduced and most of them has to be recovered at the end of the life cycle. Green building will already help the reduction of the materials and will also provide energy saving.

It is hard to implement a new system in a whole project. For this reason architectures should think of the green building principles at the beginning of the design phase. Both green building design and GSCM will result with the economic and social benefits while fitting the governmental requirements.

4.2 Developed supply chain model

A closed loop supply chain will be sustainable for construction industry that will also suit the definition of green supply chain management explained above. The following model will reduce the disposal amount of waste material with the help of recycle, repair and remanufacture operations.
Figure 4 shows the developed supply chain model, with green building design integration, for a construction firm in Turkey. By this model, construction firm will able to sell their recovered materials to the secondary markets and get profit from them. In the previous model, firm was not able to know what is happening to their waste after sending them to the landfill. Thus, this new model will be sustainable for the environment that materials will not left on the ground while giving harm to the environment. Also at the beginning of the design phase, raw material usage will be minimum according to green building principles. Usage of recyclable materials will be increased and energy efficiency technology will be preferred.

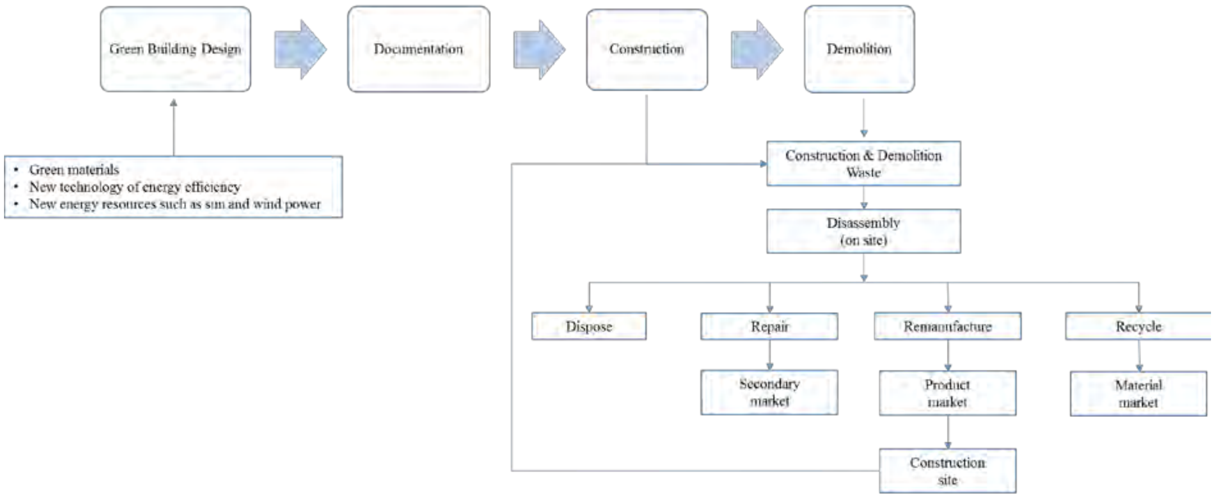

Figure 4: Developed supply chain model with green building design integration.

5. Conclusions and recommendations

The aim of this paper is to explore the cost-benefit and social-benefit reflections by the combination of GSCM and green building design, based on the literature review and case study examples from Turkey a model is built and propositions regarding Green Building operations using GSCM and reverse logistics are formulated. A green supply chain management flow chart was established to understand the CDW management system clearly in Turkey. Based on the literature review and case study examples from Turkey a model was built and propositions regarding green supply chain management and reverse logistics were formulated. To conclude this study, there are some numerical differences between the regulations of Turkey and European Union. As there are no target numbers in the excavation soil and construction and demolition waste management regulations for Turkey, the construction firms has no idea of what is the consequences of the waste sent to the landfill.

To make the supply chain sustainable, in the design phase of a construction, the materials may be used less and green materials may be preferred. As mentioned in the regulations first aim has to be to reduce waste, so it may be done with using less raw material if it is possible. This development can be provided with “green building design” principles at the beginning of the construction project.

After reducing waste, the next step is to do recovery operations for the CDW. If the construction firm will be responsible for the waste and if they can make their supply chain closed, they will also be able to re-use those secondary raw materials and remanufactured products in their own site.
The other alternative is to sell those secondary materials to the market. At future studies, customer points can be added to sell the recovered products that the firm will not use them on their site or remaining products.
For further research, a capacitated linear mathematical model which includes multi-product, multi-recovery and multi-manufacturing options, can be developed for construction firm to be able to use their own recovered products at their own construction sites. Finally it can be said that if these above mentioned improvements are applied as integrating green building design to GSCM, setting a supply chain for construction industry, the

system will be sustainable and the construction firm will be able to minimize the cost while making profit from their own waste.

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Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Vehicle Technology Selection with Integrated Fuzzy AHP-TOPSIS Method

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Abstract

Recently, Alternative Fuel Vehicles (AFV) have gathered pace in transportation due to its environmental and relative cost benefits of fuels over conventional vehicles. Hybrid, plug-in hybrid and battery electric vehicles are introduced as a new shift in transportation besides other new technologies. Due to the fact that vehicle selection problem includes some criteria, we proposed a selection model for conventional vehicles and new technology vehicles. The paper has novelty as being the first study in the literature which it aims to find the best vehicle technology for sedan cars, and it uses fuzzy integrated method for the selection of vehicle technology for sedan cars of the same brand. As new technology vehicles in the market cause uncertain decision environment and experts' evaluations have subjectivity, we used fuzzy sets to do better modelling of the problem. In the paper, we used two of the most frequently used multi-criteria methods, AHP and TOPSIS, integratedly with fuzzy sets. In the model, AHP was used to determine the weights of criteria, TOPSIS was used for ranking of alternatives. As a result of the study, diesel engine vehicle was found the best option among other alternatives with respect to considered criteria.

Keywords

Battery electric vehicles, electrification of transportation, hybrid vehicles, plug-in hybrid vehicles, multi-criteria decision making

1. Introduction

Recently, alternative energy resources' usage are being considered in many industrial areas. One of the area for alternative energy resource is transportation due to high greenhouse gas emissions generated by transportation. By considering this environmental effects and fuel resources' constraints, a new shift in transportation has gathered pace. The new shift consists plug-in hybrid and battery electric vehicles, and partially hybrid vehicles. New vehicle types have some advantages including reduction in greenhouse gas emission amount, and providing fuel efficiency, hence, they are becoming viable options for buyers in the market. Whereas they have some potential benefits, their penetration into the market is slow due to some factors (Yavuz et. al, 2015). These factors affect the buyers' behaviors in making decision about vehicle type. Some researches about the new technology have been done to define potentials and barriers of the new technology and highlight the future of the new technology. Majority of the researches on the new technology focused on plug-in hybrid electric and battery electric vehicles. Pasaoglu et. al (2015) studied about range anxiety of the new technology vehicles in some European countries. They analyzed travel data of car drivers in six European countries. The data was collected in a web-based self-administered travel diary survey as a part of a study in six European countries accounting for

75% of sales in EU. In the study, they collected information about the travel diaries including departure time and place, arrival time and place, travel distance, travel purpose, parking place, short intermediate stops (less than 10 minutes) and usage of motorways. They found that average daily driven distance in six European countries including Germany, Spain, France, Italy, Poland and the United Kingdom ranges from an average of 40 km (UK) to an average of 80 km (Poland). They also found that the parking time after the last trip may be more than 16 hours in a day. It is very important for selection of charging type of the vehicle. In Le Duigou et. al (2014)'s study, it is mentioned that the range anxiety is rather psychological than in practice, and it can be overcome by collecting the mobility behavior; average battery electric vehicles with a 50-mile range is sufficient for most daily driving needs without difficulty. For example, Chevrolet Volt uses its batteries in 40 miles, and then a small gasoline engine under the hood is operated for powering a turbine that generates more electricity for running the vehicle. They also mentioned about the range anxiety opinion of BEV supporters. The range anxiety was not a disadvantage of BEV because 97 % of all trips in the UK were shorter than 80 km, 50 % of all trips in Europe was shorter than 10 km and 80 % of all trips was shorter than 25 km and, approximately 60 % of all vehicles daily range was less than 50 km and 85 % of them were less than 100 km (Le Duigou et. al, 2014). In Greaves et. al (2014)'s study, some important findings about range and recharging times over the five weeks observations in Australia are as follows; over 90 % of day-to-day driving would be accommodated by a BEV that has the range as low as 60 km and a simple home-charge set-up, however, the incidence of tours requiring out-of-home charging is significantly high for vehicles below 170 km range, this means that out-of-home charging enables the vehicles to drive more trips. The other finding is that effective driving range factors are both how a vehicle is driven and use of electrical auxiliaries. Another finding of the study is that type of charging infrastructure and its availability are important factors for large deployment of new technology vehicles. (Greaves et. al, 2014).

Stephens (2013) mentioned about non-cost barriers of deployment for new technology vehicles. The author ranked the barriers on the basis of the assessed magnitude of their severity. These barriers are firstly limited driving range, limited fueling and charging stations, long fueling and charging times, secondly, unfamiliarity, uncertainty, regarding benefits, lack of awareness or information, thirdly, perceived differences in or predisposition for or againist advanced technology vehicles, fourthly, lack of adequate technology standardization, fifthly, limited availability and diversity of makes and models, and, finally, regulations with respect to their importance priority. In the highlit of features of the new technology, purchase cost of vehicle technology does not become uniqe factor for selection of vehicle type. When decision about selection of vehicle type is done by not only considering purchase cost but also considering other criteria, this selection becomes multi-criteria decision making problem. AHP and TOPSIS are the most frequently used multi-criteria decision making method ones which they were applied to many multi-criteria decision making problems in earlier studies. AHP is an efficient multi-criteria method to make pair-wise comparison of decision making elements. AHP method takes into account qualitative assessments of experts in decision making process, too. TOPSIS method defines positive ideal and negative ideal point, and aims to find the best alternative more distant to negative ideal point and closest to positive ideal point with respect to defined criteria. In order to benefit from these multi-criteria decision making methods, we used them integratedly to find the best alternative. The experts assess criteria and alternatives, however, each expert's assessment may contain subjectivity with respect to the others even their verbal assessments are the same. From the viewpoint of subjectivity of verbal assessments and incompleteness of information, these disadvantages must be handled for modeling. In order to handle these disadvantages, fuzzy sets are efficient to do better modelling in uncertain environments. Fuzzy sets are good at reflecting verbal assessments' subjectivity, and overcoming incomplete information under uncertainty. We used fuzzy sets with integrated AHP-TOPSIS to handle these disadvantages in decision making process. AHP method was used for determining the criteria weights, and TOPSIS method was used to determine the best alternative.

2. Vehicle Technologies

Vehicle technologies subjected to the paper are classified into their drive-trains and fuel type of the related drive-trains that provides the motion of the vehicle. These vehicles are diesel, gasoline, hybrid, plug-in hybrid and battery electric vehicles. These vehicles drive-train can work solely on whether internal combustion engine or battery electric motor or on both of them. Following table shows features of the vehicle technologies.

As seen from Table 1, each type of the vehicle technology has its own advantages and disadvantages relatively over other ones. This relativity causes uncertainty in the problem in addition to subjectivity of the experts' assessments and the new vehicle technologies' novelty in the market. As mentioned before, in order to handle these problems, we used fuzzy sets rather than crisp sets to make more precise analysis of the problem with the aim of finding the best alternative.

Table 1: Vehicle technologies

Vehicle Type	Fuel	Typical Features	Advantages	Disadvantages
Gasoline Powered	Gasoline	- Only Internal Combustion Engine(ICE) - Widespread usage	-Low purchase and maintenance cost -Fuel repletion convenience	-Less environment-friendliness due to fuel type -High oil prices
Diesel Powered	Diesel oil	- Only ICE - Widespread usage	-Respective low purchase and maintenance cost except for gasoline powered ones -Fuel repletion convenience	-Less environment-friendliness due to fuel type -High diesel oil prices
Hybrid Vehicle	Gasoline /diesel oil-electric	-ICE for propulsion and driving and small electric motor for only driving -Regenerative braking system's contribution to	-Respective environment-friendliness over conventional vehicles -Fuel saving due to its new technology	-Short range of electric motor -Respective high cost over conventional vehicles
Plug-in Hybrid Electric Vehicle	Gasoline /diesel oil-electric	-ICE and developed electric motor -Rechargeable battery with grid -Regenerative braking system's contribution to fueling for electricity -Different drive-train configurations	-Potential of receiving tax incentives due to its new technology -More environment-friendliness except for battery electric vehicles	-Rareness of usage -Rareness of public charging stations -Short driving range of electric motor -High purchase cost -High investment cost for home-charging
Battery Electric Vehicle	Electric	-Only electric motor -Large battery packs -Different charging options for fueling	-High fuel efficiency over all types of vehicles -The most environment-friendly vehicle type -Potential of receiving tax incentives due to its new technology	-Rareness of usage -Rareness of public charging stations -High charging times -Short driving range as compared to conventional cars -High investment cost for home-charging -High purchase cost

3. Methodology

In decision making problems, evaluators/experts make some assessments about problem. The same expression on the same issue may have different values according to evaluators/experts, there may not be exact value of the expression, and it causes subjectivity of human judgments. Besides them, decision making environment may usually contain uncertainty and lack of information. Fuzzy sets are very useful in handling uncertainty and reflecting human judgments to modeling by enabling flexibility in decision making problems. In order to take advantage of fuzzy sets, we used type-1 fuzzy sets with AHP and TOPSIS methods which are frequently used multi-criteria decision making methods.

We benefited from from Kahraman et al. (2014) for fuzzy AHP, and Wang and Chang (2007) for type-1 fuzzy TOPSIS method steps. Figure 1 shows the model of the problem.

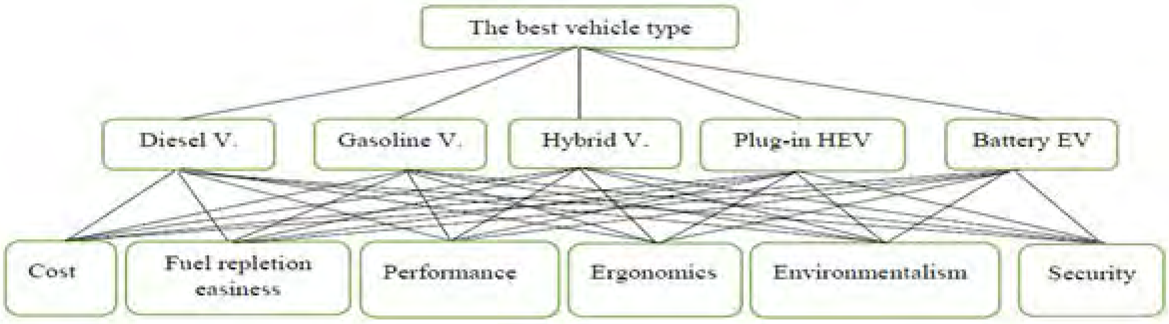

Figure 1: Multi-criteria decision making of vehicle technology selection

Until step 7 of the methodology, fuzzy AHP method will be applied. From step 8 of the methodology fuzzy TOPSIS method will be applied. Steps of fuzzy AHP-TOPSIS are as follows;

Let $C = \begin{bmatrix} C_{11} & \cdots & C_{1n} \\ \vdots & \ddots & \vdots \\ C_{n1} & \cdots & C_{nn} \end{bmatrix}$ and $A = \begin{bmatrix} A_{11} & \cdots & A_{1n} \\ \vdots & \ddots & \vdots \\ A_{m1} & \cdots & A_{mn} \end{bmatrix}$ be fuzzy pairwise comparison matrix of criteria and fuzzy pairwise comparison matrix of alternatives with respect to criteria, respectively.

Step 1. Take the average of experts' evaluations.

Step 2. Geometric mean of each criteria is found. Let $C_{ij}^{l}, C_{ij}^{m}, C_{ij}^{r}$ denote the left value, mid value and right value of ith criteria, respectively. Let GW_i including GW_i^l, GW_i^m and GW_i^r be the geometric mean of ith criteria. GW_i is found by using following equation:

$$GW_i = (GW_i^l, GW_i^m, GW_i^r) = (\prod_{j=1}^{n} C_{ij}^{l})^{1/n}, (\prod_{j=1}^{n} C_{ij}^{m})^{1/n}, (\prod_{j=1}^{n} C_{ij}^{r})^{1/n}, \; i = 1,2,\ldots n. \qquad (1.1)$$

Step 3. Let TGM including $TGM^{\,l}, TGM^{\,m}, TGM^{\,r}$ be total value of geometric means. TGM is calculated as follows:

$$TGM = (TGM^l, TGM^m, TGM^{\,r}) = \sum_{i=1}^{n} GW_i^l, \sum_{i=1}^{n} GW_i^m, \sum_{i=1}^{n} GW_i^r \qquad (1.2)$$

Step 4. Let C_{ij}^{N} including $C_{ij}^{Nl}, C_{ij}^{Nm}, C_{ij}^{Nr}$ be normalized value of C_{ij}. All left, mid and right elements of average of experts' evaluations are divided by relevant TGM value. New normalized criteria values are obtained.

$$C_{ij}^{N} = (C_{ij}^{Nl}, C_{ij}^{Nm}, C_{ij}^{Nr}) = \frac{C_{ij}^{l}}{TGM^r}, \frac{C_{ij}^{m}}{TGM^m}, \frac{C_{ij}^{r}}{TGM^l} \qquad \forall_{i,j} \qquad (1.3)$$

Step 5. Let W_i including W_i^l, W_i^m, W_i^r be weights of ith criteria. W_i are calculated as follows:

$$W_i = (W_i^l, W_i^m, W_i^r) = \sum_{j=1}^{n} C_{ij}^{Nl}, \sum_{j=1}^{n} C_{ij}^{Nm}, \sum_{j=1}^{n} C_{ij}^{Nr} \quad i = 1,2,\ldots,n. \qquad (1.4)$$

Step 6. Consistency check of pair-wise comparison is performed. If consistency check is Ok, then, we can go to fuzzy TOPSIS method. If not, we have to repeat earlier steps to find weights of criteria.

After this step fuzzy TOPSIS method will be applied.

Step 7. After all experts assessed the pair-wise comparison of alternatives by using evaluation scale, obtained values average is found.

Step 8. Maximum of all criteria are found.

$$c_j = \max_i A_{ij}^r \quad j = 1,2,\ldots,n. \tag{1.5}$$

Step 9. Even criteria may be benefit or cost criteria, we will treat them as all benefit criteria with evaluations. Let A_{ij}^N including $A_{ij}^{Nl}, A_{ij}^{Nm}, A_{ij}^{Nr}$ be normalized values of pairwise comparison of alternatives. Then, normalized pair-wise comparison values are obtained.

$$A_{ij}^N = \frac{A_{ij}^l}{c_j}, \frac{A_{ij}^m}{c_j}, \frac{A_{ij}^r}{c_j} \qquad \forall_{i,j} \tag{1.6}$$

Step 10. The criteria weights determined by fuzzy AHP method are used in fuzzy TOPSIS method, and fuzzy weighted normalized decision matrix is obtained. $\tilde{v}$ denoting the fuzzy weighted normalized values in decision matrix are as follows;

$$\tilde{v} = [\tilde{v}_{ij}]_{mxn} \text{ and } \tilde{v}_{ij} = w_i \otimes A_{ij}^N \quad i = 1,2,\ldots,m, j = 1,2,\ldots,n. \tag{1.7}$$

Step 11. Distance measure to positive ideal and negative ideal points are calculated. I^* denotes each criteria's best value, I^- denotes each criteria's worst value, $\tilde{v}_j^*$ denotes positive ideal point value, $\tilde{v}_j^-$ denotes negative ideal point value, d_i^* denotes the distance to positive ideal point , d_i^- denotes negative ideal point value of ith alternative;

$$I^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*), I^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-), \tilde{v}_j^* = (1,1,1),$$

$$\tilde{v}_j^- = (0,0,0) \quad j = 1,2,\ldots,n.$$

$$d(\tilde{v}_{ij}, \tilde{v}_j^*) = \sqrt{\frac{1}{3}x\left(\left(\tilde{v}_{ij}^l - \tilde{v}_j\right)^2 + \left(\tilde{v}_{ij}^m - \tilde{v}_j\right)^2 + \left(\tilde{v}_{ij}^r - \tilde{v}_j\right)^2\right)} \tag{1.8}$$

$$d_i^* = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^*) \qquad i = 1,2,\ldots,m. \tag{1.9}$$

$$d_i^- = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^-) \qquad i = 1,2,\ldots,m. \tag{1.10}$$

Step 12. The distance measure, more closeness to positive ideal point and more distant to negative ideal point, is calculated as in Eq. 4.3 for each alternative.

$$CC_i = \frac{d_i^-}{(d_i^* + d_i^-)} \qquad \forall_i.$$

(1.11)

Step 13. Alternatives are ranked with respect to their CC_i values in decreasing order and this order is the solution of the problem.

4. Application

We consider vehicle technology selection problem of a firm in İstanbul. The firm operates in tourism sector, and wants to purchase a group of sedan cars for its fleet. Due to the confidentiality, we do not give the firm's name and vehicle brand that will be selected. Due to the new technology vehicles, the firm regards hybrid vehicles, plug-in hybrid electric vehicles and battery electric vehicles besides conventional vehicles as alternatives. Vehicle types and their features were mentioned in the earlier section. There is not any specified criteria for the vehicle technology selection since it depends on the individual's/firm's own needs. Hence, our experts defined 6 criteria for the selection problem. These criteria are cost of vehicle, fuel repletion convenience, performance, ergonomics, environmentalism and safety. Cost of vehicle consists purchase cost, maintenance and repairment costs, and some investment costs for new technology vehicles (Home charging infrastructure investment cost). Fuel repletion convenience consists fuel repletion easiness, availability of fuel repletion, fuel repletion time. Performance consists maximum speed, city and highway speeds, performance on different weather conditions of vehicles. Ergonomics consists basic ergonomic conditions. Environmentalism consists tailpipe emissions by the type of used fuel. Safety consists driving safety, vehicle's danger for passengers and pedestrians, and in case of accident. We have three experts who make pairwise comparisons for the selection problem. They use type-1 fuzzy sets in the evaluations due to the fact that fuzzy sets may reflect the experts' opinions and handle uncertainty more better than crisp values. Firstly, the experts make the evaluation on criteria to define the criteria weights by using scale in Table 2.

Table 2: Fuzzy scale for criteria evaluation

Linguistic Term	Fuzzy Values
Absolutely Strong (AS)	(2,5/2,3)
Very Strong (VS)	(3/2,2,5/2)
Strong (S)	(1,3/2,2)
Slightly Strong (SS)	(1,1,3/2)
Equal (E)	(1,1,1)
Slightly Weak (SW)	(2/3,1,1)
Weak (W)	(1/2,2/3,1)
Very Weak (VW)	(2/5,1/2,2/3)
Absolutely Weak (AW)	(1/3,2/5,1/2)

For simplicity, we abbreviate criteria. CV, FRC, P, E, EN and S denotes cost of vehicle, fuel repletion convenience, performance, ergonomics, environmentalism and safety, respectively. A_1, A_2, A_3, A_4 and A_5 denotes gasoline, diesel, hybrid, plug-in hybrid electric and battery electric vehicles, respectively. We obtained table 3 by the evaluation of the experts.

Table 3: Experts linguistic evaluation of the criteria

		CV	FRC	P	E	EN	S
	E_1	E	VS	VS	SS	S	AS
CV	E_2	E	AS	SS	S	E	S
	E_3	E	VS	VS	VS	SS	S
	E_1	VW	E	VS	VS	SS	AS
FRC	E_2	AW	E	S	S	S	VS
	E_3	VW	E	S	S	S	SS
	E_1	VW	VW	E	E	SW	SS
P	E_2	SW	W	E	SS	E	W
	E_3	VW	W	E	VS	SS	E
	E_1	SW	VW	E	E	E	SW
E	E_2	W	W	SW	E	W	VW
	E_3	VW	W	VW	E	E	W
	E_1	W	SW	SS	E	E	E
EN	E_2	E	W	E	S	E	W
	E_3	SW	W	SW	E	E	E
	E_1	AW	AW	SW	SS	E	E
S	E_2	W	VW	S	VS	S	E
	E_3	W	SW	E	S	E	E

When we apply step 1 of the model, we can obtain table 4. Then, by applying Eq.s 1.1-1.2, we obtain GW and TGM values as shown in table 5.

Table 4: Average evaluation matrix of the criteria

	CV	**FRC**	**P**	**E**	**EN**	**S**
CV	(1,1,1)	(1.667,2.167,2.667)	(1.333,1.667,2.167)	(1.167,1.5,2)	(1,1.167,1.5)	(1.333,1.833,2.333)
FRC	(0.377,0.467,0.613)	(1,1,1)	(1.167,1.667,2.167)	(1.167,1.667,2.167)	(1,1.333,1.833)	(1.5,1.833,2.333)
P	(0.49,0.667,0.78)	(0.467,0.613,0.89)	(1,1,1)	(1.167,1.333,1.667)	(0.89,1,1.167)	(0.833,0.89,1.167)
E	(0.523,0.723,0.89)	(0.467,0.613,0.89)	(0.69,0.833,0.89)	(1,1,1)	(0.833,0.89,1)	(0.523,0.723,0.89)
EN	(0.723,0.89,1)	(0.557,0.78,1)	(0.89,1,1.167)	(1,1.167,1.333)	(1,1,1)	(0.833,0.89,1)
S	(0.443,0.58,0.833)	(0.467,0.633,0.723)	(0.89,1.167,1.333)	(1.167,1.5,2)	(1,1.167,1.333)	(1,1,1)

Table 5: Geometric means and total geometric mean value of the criteria

Criteria	**GW**
CV	(1.23,1.504,1.853)
FRC	(0.957,1.212,1.52)
P	(0.763,0.886,1.079)
E	(0.647,0.787,0.925)
EN	(0.818,0.947,1.076)
S	(0.774,0.953,1.135)
TGM	(5.189,6.289,7.588)

For example, we can get geometric mean of CV as following;

$$GW_1 = \left((1x1.667x1.333x1.167x1x1.333)^{\frac{1}{6}}, (1x2.167x1.667x1.5x1.167x1.833)^{\frac{1}{6}}, (1x2.667x2.167x2x1.5x2.333)^{\frac{1}{6}} \right)$$

When we apply Eq. 1.3, we obtain the normalized criteria matrix as shown in table 6.

Table 6: Normalized matrix of criteria

	CV	**FRC**	**P**	**E**	**EN**	**S**
CV	(0.132,0.159,0.193)	(0.22,0.345,0.514)	(0.176,0.265,0.418)	(0.154,0.239,0.385)	(0.132,0.186,0.289)	(0.176,0.292,0.45)
FRC	(0.05,0.075,0.118)	(0.132,0.159,0.193)	(0.154,0.265,0.417)	(0.154,0.265,0.418)	(0.32,0.212,0.353)	(0.198,0.292,0.45)
P	(0.065,0.106,0.15)	(0.062,0.098,0.172)	(0.132,0.159,0.193)	(0.154,0.212,0.322)	(0.117,0.159,0.225)	(0.11,0.142,0.225)
E	(0.069,0.115,0.172)	(0.062,0.098,0.172)	(0.091,0.133,0.172)	(0.132,0.159,0.193)	(0.11,0.142,0.193)	(0.069,0.115,0.172)
EN	(0.095,0.142,0.193)	(0.073,0.124,0.193)	(0.117,0.159,0.225)	(0.132,0.186,0.257)	(0.132,0.159,0.193)	(0.11,0.142,0.193)
S	(0.058,0.092,0.161)	(0.062,0.1,0.139)	(0.117,0.186,0.257)	(0.154,0.239,0.385)	(0.132,0.186,0.257)	(0.132,0.159,0.193)

For example, we can get C_{11}^{N} value as following;

$$\left((1/7.588), (1/6.289), (1/5.189) \right) = (0.132, 0.159, 0.193)$$

When we apply division operation ,done above, to the normalized matrix of criteria, we obtain values of the criteria weights as (0.165,0.247,0.375), (0.136,0.211,0.325), (0.106,0.146,0.214), (0.089,0.127,0.179), (0.11,0.152,0.209), (0.109,0.16,0.232), respectively. If we check consistency of comparisons for criteria, consistency ratio is found 0.0483. Then, we can conclude that comparisons are consistent. The experts use the following scale for alternatives' comparisons with respect to the criteria.

Table 7: Fuzzy scale for alternative evaluation

Linguistic Term	Fuzzy Values
Very Poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Moderately Poor (MP)	(1,3,5)
Moderate (M)	(3,5,7)
Moderately Good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very Good (VG)	(9,10,10)

Linguistic evaluations of alternatives by the experts are represented in table 8.

Table 8: Linguistic evaluations of alternatives

		CV	FRC	P	E	EN	S
A_1	E_1	G	VG	MG	M	P	M
	E_2	G	VG	G	VG	MG	VG
	E_3	G	VG	G	VG	P	G
A_2	E_1	VG	VG	G	M	G	M
	E_2	VG	VG	VG	G	G	VG
	E_3	VG	VG	VG	VG	MP	VG
A_3	E_1	MG	VG	G	MP	M	M
	E_2	MG	VG	G	VG	VG	VG
	E_3	MG	VG	G	VG	MG	MG
A_4	E_1	P	MG	G	MP	MG	MP
	E_2	P	VG	MP	VG	VG	MG
	E_3	P	M	M	MG	G	MP
A_5	E_1	VP	VP	M	MP	G	P
	E_2	VP	VP	VP	VG	VG	MG
	E_3	VP	P	P	M	VG	MP

By applying Eq.s 1.5-1.6 in Steps 8-9, we obtain normalized matrix of alternatives as shown in table 10.

Table 9: Average value of alternative evaluations

	CV	FRC	P	E	EN	S
A_1	(7,9,10)	(9,10,10)	(6.333,8.333,9.667)	(7,8.333,9)	(1.667,3,5)	(6.333,8,9)
A_2	(9,10,10)	(9,10,109	(8.333,9.667,10)	(6.333,8,9)	(5,7,8.333)	(7,8.333,9)
A_3	(5,7,9)	(9,10,10)	(7,9,10)	(6.333,7.667,8.333)	(5.667,7.333,8.667)	(5.667,7.333,8.667)
A_4	(0,1,3)	(5.667,7.333,8.667)	(3.667,5.667,7.333)	(5,6.667,8)	(7,8.667,9.667)	(2.333,4.333,6.333)
A_5	(0,0,1)	(0,0.333,1.667)	(1,2,3.667)	(4.333,6,7.333)	(8.333,9.667,10)	(2,3.667,5.667)

Table 10: Normalized matrix of alternatives

	CV	FRC	P	E	EN	S
	(0.165,0.247,0.375)	(0.136,0.211,0.325)	(0.106,0.146,0.214)	(0.089,0.127,0.179)	(0.11,0.152,0.209)	(0.109,0.16,0.232)
A_1	(0.7,0.9,1)	(0.9,1,1)	(0.633,0.833,0.967)	(0.778,0.926,1)	(0.167,0.3,0.5)	(0.704,0.889,1)
A_2	(0.9,1,1)	(0.9,1,1)	(0.833,0.967,1)	(0.704,0.889,1)	(0.5,0.7,0.833)	(0.778,0.926,1)
A_3	(0.5,0.7,0.9)	(0.9,1,1)	(0.7,0.9,1)	(0.704,0.852,0.926)	(0.567,0.733,0.867)	(0.63,0.815,0.963)
A_4	(0,0.1,0.3)	(0.567,0.733,0.867)	(0.367,0.567,0.733)	(0.556,0.741,0.889)	(0.7,0.867,0.967)	(0.259,0.481,0.704)
A_5	(0,0,0.1)	(0,0.033,0.167)	(0.1,0.2,0.367)	(0.481,0.667,0.815)	(0.833,0.967,1)	(0.222,0.407,0.63)

For example, we can obtain A_{11}^N value as dividing all values in the first column by 10 which is the maximum element of the first column numbers.

A_{11}^N =(7/10, 9/10, 10/10) = (0.7, 0.9, 1).

When we apply Eq. 1.7 in Step 10, we obtain the weighted normalized matrix as in table 11. Then, by applying Eq.s 1.9-1.10 and 1.11 in steps 11-12, we obtain results as shown in table 12.

Table 11: Weighted normalized matrix

	CV	FRC	P	E	EN	S
A_1	(0.116,0.222,0.375)	(0.122,0.211,0.325)	(0.067,0.122,0.207)	(0.069,0.118,0.179)	(0.018,0.046,0.105)	(0.077,0.142,0.232)
A_2	(0.149,0.247,0.375)	(0.122,0.211,0.325)	(0.088,0.141,0.214)	(0.063,0.113,0.179)	(0.055,0.106,0.174)	(0.085,0.148,0.232)
A_3	(0.083,0.173,0.338)	(0.122,0.211,0.325)	(0.074,0.131,0.214)	(0.063,0.108,0.166)	(0.062,0.111,0.181)	(0.069,0.13,0.223)
A_4	(0,0.025,0.113)	(0.077,0.155,0.282)	(0.039,0.083,0.157)	(0.049,0.094,0.159)	(0.077,0.132,0.202)	(0.028,0.077,0.163)
A_5	(0,0,0.038)	(0,0.007,0.054)	(0.011,0.029,0.079)	(0.043,0.085,0.146)	(0.092,0.147,0.2099	(0.024,0.065,0.146)

Table 12: Results

	d_i^*	d_i^-	CC_i	Rank
A_1	5.098	0.999	0.164	1
A_2	5.005	1.079	0.177	3
A_3	5.087	1.011	0.166	2
A_4	5.371	0.724	0.119	4
A_5	5.61	0.453	0.075	5

5. Conclusions and Suggestions

In recent times, alternative fuel technology vehicles are penetrating into the market due to environmental awareness and reduction in fossil derived fuels. Many researchers have been studying on the new technology by conducting surveys, doing business scenarios of these vehicles' large deployment in the market, analyzing buyers' desires and preferences. Some of alternative fuel vehicles which are subjected to this paper are hybrid, plug-in hybrid electric and battery electric vehicle. In the paper, we tried to determine the best vehicle technology for a firm operating in İstanbul. Alternatives of vehicle technology selection problem are conventional passenger cars (sedan cars) in addition to hybrid, plug-in hybrid electric and battery electric cars. By using integrated fuzzy AHP-TOPSIS method which fuzzy AHP determines the weights of the criteria and fuzzy TOPSIS ranks the alternatives, we have found that the best alternative is diesel powered vehicle among the alternatives. Hybrid vehicle is the second ranked, and gasoline powered vehicle is the third ranked alternative. Remaining alternatives are plug-in hybrid electric vehicle and battery electric vehicle in order. We can conclude that some cost and non-cost barriers have to be overcame for alternative fuel vehicle technologies subjected to the paper. From the criteria weights defined by the experts' evaluations, we can conclude that most important criteria are cost and fuel repletion convenience, and improvements have to focus on these barriers. Moreover, for further researches, problem can be modeled and solved under different cost-fuel repletion evaluation scenarios for potential projection of the new technology in the future. Besides these, different types of fuzzy sets and different multi-criteria methods can be used for the problem, and the findings of our paper can be compared with their results.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Volume Flexibility in Robust Design of Supply Flow under Operational and Disruption Risks

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Abstract

This paper focuses on the robust design of the supply flow by incorporating strategic stock and contingent sourcing in order to deal with operational risks and disruptions of suppliers in future. We consider a firm with two suppliers where the main supplier is cost-effective but prone to disruptions and the back-up supplier is reliable but expensive due to built-in volume flexibility capabilities. The design problem is to determine optimal strategic stock level and response speed of volume-flexible back-up supplier in order to achieve a robust supply flow. Since it might be difficult to estimate the probability of disruptions, we aim to find an equitable solution which has an efficient performance with respect to all plausible future scenarios. For this purpose, we develop an MIP robust optimization model which includes the Ordered Weighted Averaging (OWA) aggregation operator in the objective function. Furthermore, this problem may include a large number of scenarios which creates a significant challenge in computation. In order to resolve this computational complexity, we propose a novel clustering based MIP scenario reduction model (CBRSM). The results show that the reduced scenario set achieved by CBSRM is a good approximation of the original scenario set.

Keywords

Volume flexibility, Recovery time, Congestion, Solution robustness, Scenario reduction

1. Introduction

Within the last decade, there have been several instances of supply chain breakdown as a result of disruptions in suppliers. Ericsson lost 400 million euros after a random lightning bolt struck its semiconductors supplier firm in New Mexico in 2000 (Tang, 2007). After the Japan tsunami in 2011, General Motors suspended production in its assembly plant in USA due to the shortage of parts supplied by Japanese (Ghadge et al., 2011). In addition to disruptions, the supply flow may fluctuate as a result of operational risks in suppliers such as machine breakdowns. Therefore, resilience strategies which enable the supply chain to adapt its structure in order to survive from both operational risks and disruptions of suppliers should be employed (Klibi & Martel, 2012). To this end, a volume flexible back-up supplier and strategic stock could be incorporated in the supply chain structure in order to cover disruptions and operational risks of main suppliers respectively. In using the back-up supplier as a supply chain cost-efficient strategy to deal with supply disruptions, it should be considered that the back-up supplier may not be able to provide the required capacity instantaneously since some portion of the added capacity may be lost during the recovery time (Matta et al., 2007). In order to recover from the capacity loss during the recovery time, the strategic stock could also be used (Schmitt, 2011). However, the required level of strategic stock depends on available capacity of the back-up supplier during the recovery time. The speed of the back-up supplier to provide the required capacity and the workload congestion created as a result of randomness associated with parts arrival and back-up supplier production rate are the parameters which affect the amount of available capacity during the recovery time. Ignoring these parameters may lead to the underestimation of the required strategic stock which in turn may create product shortage within the recovery time. The level of strategic stock and response speed of back-up supplier are key strategic level supply chain design decisions that may significantly impact the operation costs in the future. Therefore, this paper focuses on identifying the optimal mix of strategic stock and response speed of the back-up supplier in order to create a robust supply flow. For this purpose, the impact of the aforementioned parameters which affect the available capacity during the recovery time is considered in the decision-making process.

In order to achieve a robust supply chain network with capability to provide sustainable value creation within the planning horizon considered, the strategic level supply chain design decisions should be determined by considering all plausible future scenarios (e.g. minor operational interruptions as well as major disruption events). In this setting, the design decisions could be identified such that the expected costs of all operational and contingency actions required to satisfy customer demand across all scenarios to be minimized. This approach is implemented through the stochastic programming. If the available information is not sufficient to estimate the probability of scenarios, a robust optimization model could be used (Klibi et al., 2010). Both of these approaches enable the decision makers to determine the strategic level supply chain design decisions considering all scenarios however there is a significant challenge in computations with the problems including large number of scenarios (Torabi et al., 2015). In order to resolve this computational complexity, we propose a novel MIP clustering based scenario reduction technique in this paper. This approach selects a small set of scenarios which represents reasonably good approximations of the scenario set. The performance of the proposed method in achieving high quality solutions is compared with clustering feature in Matlab. The rest of the paper is organized as follows: Section 2 reviews the relevant literature; Section 3 presents the problem statements; Sections 4 describes the solution methodology, which includes robust model formulation and scenario reduction technique; the numerical results are presented in Section 5; and Section 6 states the conclusions and future research areas.

2. Literature Review

Recently, a significant portion of the literature has been assigned to robust design of supply chain. A supply chain design is identified as robust if it has capability to sustain value creation under operational risks and major disruptions in future (Klibi et al., 2010). A robust supply chain could be achieved by incorporating a combination of flexibility and redundancy based capabilities in the supply chain structure (Iris et al, 2015). The flexibility based capabilities includes having back-up suppliers, volume flexibility, process flexibility and flexible transportation system. On the other hand, the redundancy based capabilities includes having multiple suppliers, strategic stock and extra capacity (Hohenstein et al., 2015). In supply chain risk management literature, the strategic stock along with flexible back-up supplier has been incorporated in the supply chain structure in order to mitigate the impacts of supplier disruptions. Kouvelis & Li (2012) investigate the potential application of strategic stock and emergency order to back-up suppliers versus traditional safety lead time to cope with late delivery of order. They conclude that strategic stock and emergency order to back-up suppliers are cost-efficient when the coefficient of variation of lead time is high. Qi (2013) assess the optimal sourcing and replenishment strategies of a retailer sourcing from an unreliable primary supplier and an expensive back-up supplier. The conclusion is that the benefit of having a back-up supplier increases as the speed of primary supplier in recovery from disruption decreases. The supply chain robustness may degrade if it is assumed that the backup supplier could provide the required capacity immediately after the failure of main supplier. The reasons might be frequent occurrences of the system breakdown, rework, scrap and low skill of the operator to work with new configuration during the recovery time (Matta et al., 2007). The level of backup capacity available during the recovery time depends on the backup supplier machine configurations (Wang & Koren, 2012). In a pure parallel configuration, there is a higher level of available capacity during the recovery time because of the faster transition speed to the required capacity level. However, this configuration requires machines with capability to process all manufacturing steps which increases the investment cost. Therefore, the configuration selection of the backup supplier can impact the supply chain robustness and it should be considered in the design stage where the tradeoff is between the cost and response speed.

In order to evaluate the robustness of a supply chain design with respect to future disruption occurrences, the concept of solution robustness has been applied as a performance measure in several papers. A solution is called robust if it remains close to optimal for any occurrence of scenarios. Baghalian et al. (2013) identify the optimal location of facilities subject to supply side disruptions by minimizing the trade-off between expected cost of supply chain and solution robustness. They compute the solution robustness based on the difference between the cost of each scenario and expected cost of all scenarios. In the same context of problems, Snyder & Daskin (2006) p-robust formulation minimizes the expected cost of the supply chain while bounding the relative regret in each scenario to be lower than the constant p. They compute the regret of a solution in a given scenario as the difference between the cost of the solution in that scenario and the cost of the optimal solution for that scenario. Sawik, (2014) develop a combinatorial stochastic optimization formulation in order to identify robust solutions in a supplier selection and demand allocation problem subject to supplier disruptions. He tries to minimize the ordered weighted averaging aggregation of the expected value and the expected worst-case value of the objective function in order to obtain an equitably efficient solution. Such a solution is expected to equitably optimize the performance of a supply chain with respect to all plausible scenarios as well as in the worst-case scenario. Although the aforementioned approaches could be applied in order to achieve solution robustness in supply chain network design when the probabilities of scenarios are available, there is an open challenge for the case in which the scenario probabilities are unavailable. Kouvelis & Yu (1997) propose a robust optimization formulation which can be seen as an extension of stochastic programming with a min-max regret criterion in the objective function instead of the expected cost. The min-max approach could be used to design supply chain network when scenario probabilities are not available. However it is known to be too pessimistic because of considering only the worst case scenario. In this work, we focus on the robust design of the supply flow to cope with disruptions by incorporating two well known risk mitigation strategies; strategic stock and volume flexible back-up supplier. Our objective is to determine optimal level of strategic stock and the machine configuration of the back-up supplier while considering the impact of recovery time characteristics such as congestion over the available capacity. Since it might be difficult to have an estimation of low frequency high impact disruptions, we aim to develop a decision making tool which help us to achieve solution robustness when scenarios probabilities are not available.

3. Problem Statement

In this paper, we consider a single product supply chain that includes a manufacturing plant with dual sourcing. The main supplier of the manufacturing plant is cost-effective as a result of dedicated facilities though prone to disruptions during which it may be partially or completely unavailable. There is a back-up supplier located in a low-risk region that is available when the main supplier is unavailable. The back-up supplier has volume-flexible production facilities where it can scale up its capacity, however this scalability increases the production cost. Demand in the normal periods can be met by the main supplier. In the case of minor disruption occurrences, the strategic stock which is provided at the beginning of the planning horizon can cover the losses. When the main supplier fails due to a major disruption, the back-up supplier increases its capacity to meet the plant demand. The target capacity is gradually achieved within the recovery time because of the non-steady production during this period (Matta et al., 2007). Therefore a random fraction of the target capacity is available during the recovery time. In addition to these, shifting the demand to the back-up supplier when it is not fully capable of producing at the required rate during the recovery time can create an overflow of material. This congestion would decrease the throughput during the recovery time due to the increase in the lead time. The available capacity of the back-up supplier within the recovery time is important and it should be considered in the design stage, since the supply chain incurs shortage costs if the available capacity level during this period is lower than the required capacity. Furthermore, the amount of the available capacity during the recovery time depends on the back-up supplier's machine configuration (Wang & Koren, 2012). In addition to this, the strategic stock could also be used to cover the losses during the recovery time (Schmitt, 2011). Therefore, the objective of this paper is to determine the appropriate strategic stock level and machine configuration of the back-up supplier while considering the available capacity within the recovery time.

The set of random parameters in this problem includes the occurrence of minor and major disruptions in the main supplier and the portion of the added capacity to the back-up supplier which is available during the recovery time. In addition to this, the supply chain performance should be investigated in a multi period planning horizon subject to disruption occurrences which increases the number of plausible scenarios in future. As a result of these, the strategic design decisions in this problem should be identified by considering a large number of plausible future scenarios which lead to a significant computational complexity. Therefore, selecting a few representative scenarios of the original scenario set may help in order to improve the solution time.

4. Solution Methodology

In order to find the optimal back-up supplier machine configuration and the level of strategic stock, a two-step solution methodology is proposed as illustrated in Figure 1. The first step is a mixed integer programming (MIP) based scenario clustering model which reduces the set of plausible future scenarios into a smaller set by selecting the most representative scenarios. The second step is an MIP robust optimization model which is designed to achieve solution robustness when scenario probabilities are not available. This model identifies the machine configuration of the back-up supplier and the level of strategic stock by considering the representative scenarios which are achieved in step one. The selections of back-up supplier machine configuration and the level of strategic stock are based on the trade-off which exists between investment cost and operational cost of supply chain with respect to representative scenarios.

The MIP robust model in step two is the stochastic version of an MIP deterministic capacity planning model. The contingency capacity plan of supply flow when the main supplier becomes disrupted is generated through MIP capacity planning model. In order to have an estimation of the available production capacity during the recovery time, the impact of work load accumulation over the system throughput is represented in the MIP capacity planning model. This model is represented in Section 4.2. The following section presents the first step of the solution methodology which is the MIP clustering based scenario reduction model.

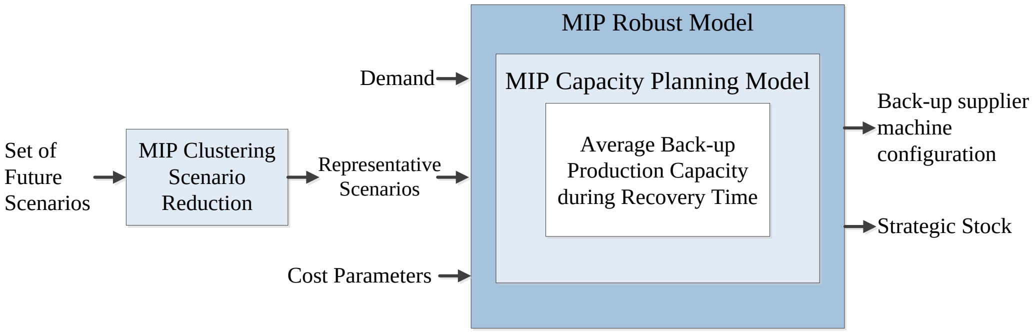

Figure 1: Solution Methodology

4.1 Clustering based Scenario Reduction Model

The MIP robust model in this paper may include a large number of random scenarios that makes it very hard to solve. To overcome this difficulty in such problems, some approximation methods have been presented in literature which reduces the dimension of the problem by determining a subset of the scenario set. Li & Floudas (2014) present an MIP scenario reduction model which minimizes the probabilistic distance between the original and reduced input scenario distribution. The probabilistic distance depends on scenario probabilities and distances between scenario values. The distance $d_{i,j}$ between any two scenarios i, j is measured based on the following metric:

$$d_{i,j} = \sum_{q=1}^{Q}\sum_{t=1}^{T}\left|\theta_t^{i,q} - \theta_t^{j,q}\right| \tag{1}$$

Where $t \in T$ represents time, $q \in Q$ is the random parameter and $\theta_t^{i,q}$ is a binary variable which becomes 1 if random parameter q occurs at time t in the scenario i and 0 otherwise. Eventually, scenarios are deleted when they are close or have small probabilities. In order to reduce the number of scenarios in this paper, an MIP model is proposed which group scenarios into different clusters. Any two scenarios will be assigned to a cluster if their distance is lower than a given admissible distance. The distance between scenarios is measured by the metric proposed by Li & Floudas (2014) metric. In order to prevent the model to assign one cluster to each scenario, the objective function of the model (2) is designed to reduce the total number of clusters.

$$Min \sum_{k \in NC} Y_k \tag{2}$$

The binary decision variable Y_k equals to 1 if the cluster k is generated and $NC = \{1,...,K\}$ is the set of clusters with maximum of K. The parameter K could be equal to the total number of scenarios. In order to decide which scenarios should be assigned to a cluster, the binary input parameter Z_{ij} should be determined. It becomes 1 if $d_{i,j} \leq \alpha$ where α represents the admissible distance. The binary decision variable X_{ik} determines if scenario i is assigned to cluster k. Thus, scenario i and j will be assigned to cluster k only if Z_{ij} equals to 1 (3). The set $NS = \{1,...,S\}$ represents the original scenario set.

$$X_{ik} + X_{jk} \leq 1 + Z_{ij} \qquad \forall k \in NC,\ \forall i, j \in NS \tag{3}$$

$$\sum_{k \in NC} X_{ik} = 1 \qquad \forall i \in NS \tag{4}$$

$$\sum_{i \in NS} X_{ik} \leq MY_k \qquad \forall k \in NC \tag{5}$$

The constraint (4) controls the model in order to assign each scenario to one cluster only. Finally, each scenario can be assigned to a cluster only if that cluster is generated (5) whereas M represents a big number. The output of the above MIP model is a set of clusters where each cluster includes scenarios whose distance from each other is lower than an admissible distance. Next, the set of clusters will be input to another MIP model which identifies the cluster centers. The scenarios correspond to cluster centers are the representative scenarios. In order to determine a cluster center, the objective function of the second MIP model (6) is designed such that it minimizes the distance between the cluster center and the rest of the scenarios in that cluster. The decision variable Y_{ik} is only 1 if scenario i is identified as the center of cluster k. Note that the X_{jk} is a binary input parameter which becomes 1 if scenario j is assigned to cluster k and it is an input from the first MIP model.

$$Min \sum_{k\in NC}\sum_{i\in NS}\sum_{j\in NS} d_{ij}Y_{ik}X_{jk} \tag{6}$$

$$Y_{ik} \le X_{ik} \quad \forall k \in NC,\ \forall i \in NS \tag{7}$$

$$\sum_{i\in NS} Y_{ik} = 1 \quad \forall k \in NC \tag{8}$$

The constraint (7) guarantees that a scenario could be assigned as the center of a cluster only if it belongs to that cluster. Eventually, each cluster should only have one cluster center (8). The cluster centers are representative scenarios. The MIP robust model identifies the strategic design decisions by considering representative scenarios. It computes the operational cost of a design decision by generating the contingency capacity plans of representative scenarios. The following section describes the MIP contingency capacity planning model.

4.2 Capacity Planning Model

The production quantity of the main supplier x_t^d and the back-up supplier x_t^r, the amount of added capacity to back-up supplier Δ_t^+, lost demand l_t and level of strategic stock ν_t within the planning horizon are determined by MIP contingency capacity planning model. In addition to these, the model determines the optimal machine configuration of back-up supplier y_j and the initial level of strategic stock ν for a given disruption scenario. The objective of the model is to minimize the investment cost plus the total operational costs (9). The cost parameters include the investment cost of machine configuration j represented by C_j, the purchasing/manufacturing cost of initial strategic stock A, the production cost of main supplier R, the production cost of back-up supplier W, the shortage cost O, the capacity addition cost E and the strategic stock holding cost H.

$$Min \sum_{j\in J} C_j y_j + A\nu + \sum_{t\in T} Rx_t^d + Wx_t^r + E\Delta_t^+ + Ol_t + H\nu_t \tag{9}$$

The flow of material is represented through constraints (10) to (12). The demand at any period is satisfied by production of the main and the back-up supplier and strategic stock. The unsatisfied demand is assumed to be lost (10). The binary parameter G_t equals to 1 if a major disruption happens. The binary parameter F_t equals to 1 if a minor disruption happens. The level of strategic stock at any period does not change if there is no disruption (11). The level of strategic stock at the beginning of the planning horizon equals to ν (12). The constraint (13) guarantees that only one configuration would be selected out of possible back-up supplier machine configurations in set J. The impact of disruptions over the main supplier capacity is represented by (14) where C_d is the maximum capacity of main supplier. The parameter B is the intensity of minor disruption. The level of work in process in the main supplier and the back-up supplier are identified through constraints (15) and (16) respectively. The WIP level at the beginning of each period is the WIP level of the previous period ω_{t-1} plus the amount of raw material released ρ_t. The WIP level at the end of each period ω_t is the difference between the level of WIP at the beginning of that period and the production level x_t.

$$D_t = x_t^d + x_t^r + l_t + (G_t + F_t)(\nu_{t-1} - i_t) \quad \forall\ t \in T \tag{10}$$

$$\nu_t = (1 - G_t - F_t)\nu_{t-1} + (G_t + F_t)i_t \quad \forall\ t \in T \tag{11}$$

$$\nu_0 = \nu \tag{12}$$

$$\sum_{j\in J} C_j y_j = 1 \tag{13}$$

$$x_t^d \le (1 - F_t B - G_t)C_d \quad \forall\ t \in T \tag{14}$$

$$\omega_t^d = \omega_{t-1}^d + \rho_t^d - x_t^d \quad \forall\ t \in T \tag{15}$$

$$\omega_t^r = \omega_{t-1}^r + \rho_t^r - x_t^r \quad \forall\ t \in T \tag{16}$$

The capacity balance equations of the back-up supplier are represented in constraints (17) and (18). The nominal capacity ξ_t determines the amount of capacity that the system is set to reach (17). It is equal to the nominal capacity of the previous period plus the amount of added capacity Δ_t^+ or minus the amount of removed capacity Δ_t^-. In the periods where capacity is added, the actual capacity τ_t is the nominal capacity of the previous period plus the amount of added capacity that is available during recovery time u_t. The actual capacity is equal to the nominal capacity in periods with capacity decrease (18). The amount of added capacity available during the recovery time is bounded by a fraction $U_{j,i}$ of the added capacity where $U_{j,i}$ depends on the back-up supplier machine configuration y_j and the level of the capacity loss realized during recovery time K_t^i (19). Note that y_j and K_t^i are binary input parameters and $\sum_{i \in I} K_t^i = 1$. The back-up supplier production at any period is less than the actual capacity (20). The effect of congestion observed at the back-up supplier during the recovery time is represented with an M/G/1 queueing based nonlinear clearing function which is proposed by Missbauer (2002). In order to solve the complexity associated with the nonlinearity of clearing function, we apply an outer approximation. Thus the clearing function is represented through a set of M planes in (21).

$$\xi_t = \xi_{t-1} + \Delta_t^+ - \Delta_t^- \qquad \forall\, t \in T \tag{17}$$

$$\tau_t = \xi_{t-1} + u_t - \Delta_t^- \qquad \forall\, t \in T \tag{18}$$

$$u_t \leq (\sum_{i \in I} K_t^i U_{j,i})\Delta_t^+ + \Psi(1 - y_j) \qquad \forall\, t \in T \tag{19}$$

$$x_t^r \leq \tau_t \qquad \forall\, t \in T \tag{20}$$

$$x_t^r \leq A_m(\omega_{t-1}^r + \rho_t^r) + B_m \tau_t - G_m \qquad \forall\, t \in T \qquad \forall m \in M \tag{21}$$

$$\begin{gathered} y_j \in \{0,1\},\ \nu \geq 0,\ x_t^d \geq 0,\ x_t^r \geq 0,\ l_t \geq 0,\ v_t \geq 0,\ i_t \geq 0,\ \omega_t^d \geq 0,\ \omega_t^r \geq 0 \\ \rho_t^d \geq 0,\ \rho_t^r \geq 0,\ \xi_t \geq 0,\ \tau_t \geq 0,\ \Delta_t^+ \geq 0,\ \Delta_t^- \geq 0,\ u_t \geq 0 \end{gathered} \tag{22}$$

The back-up supplier machine configuration y_j and the initial level of strategic stock ν are required to be identified at the design stage of the supply chain. To this end, an MIP robust model is presented in section 4.3 which determines these strategic design decisions by considering all plausible future disruption scenarios.

4.3 Robust Model

The ordered weighted averaging (OWA) aggregation operator could be applied to multi objective decision making problems where all objectives are equally important to the decision maker (Sawik, 2014). In such a problem context, the objective is to generate a fair solution, in which all normalized objective function values are as much close to each other as possible. The OWA aggregation operator provides the sum of weighted objective function values which have been sorted in the order of the largest value, the two largest values and so on. Liu & Papageorgiou (2013) provide a formulation in order to transfer the OWA aggregation operator to the objective function of a linear minimization problem. Later on, Liu et al. (2014) prove that assignment of equal weights to the optimization problem in (Liu & Papageorgiou, 2013) provide a fair as well as a Pareto optimal solution. In this paper, we will treat each scenario as an objective. Since the scenario probabilities are not available, all objectives can be treated as equally important. Our objective is to achieve solution robustness when scenario probabilities are not available. Therefore, we will try to find a fair solution, in which the relative regrets of all scenarios are as much close to each other as possible. We will apply the formulation proposed in (Liu & Papageorgiou, 2013) in order to represent the OWA aggregation operator in the objective function. Since all scenarios are equally important, we will assign identical weights to all objectives. The formulation of OWA aggregation operator in the robust model according to Liu and Papageorgiou (2013) approach is represented in (23) and (24).

$$Min \sum_{l \ in\ S} \left(l\lambda_l + \sum_{s \ in\ S} \delta_{sl} \right) \tag{23}$$

Subject To:

$$\lambda_l + \delta_{sl} \geq f_s \qquad \forall l,\ \forall s \in S \tag{24}$$

The above formulation provides the summation of largest value, the two largest values, the three largest values, etc of outcome values f_s. The relative regret of each scenario s is represented by f_s. The variable λ_l is unrestricted and the non-negative variable δ_{sl} represents the upside deviation of f_s from the value of λ_l. The constraint (25) determines the relative regret of each scenario based on the difference between the cost of the solution in that scenario Z_s (26) and the cost of the optimal solution for that scenario Z_s^*. Note that Z_s^* is an input parameter which is defined as the total cost of MIP contingency capacity planning model for scenario s.

$$f_s = \frac{Z_s - Z_s^*}{Z_s^*} \qquad \forall s \in S \tag{25}$$

$$Z_s = \sum_{j \in J} C_j y_j + Av + \sum_{t \in T} Rx_{s,t}^d + Wx_{s,t}^r + E\Delta_{s,t}^+ + Ol_{s,t} + H\nu_{s,t} \qquad \forall s \in S \tag{26}$$

$$(10) \; to \; (21) \qquad \forall s \in S \tag{27}$$

The MIP robust model considers the solution robustness as the performance measure in the selection of the back-up supplier machine configuration and the initial level of strategic stock. The Min-Max formulation is a common approach in robust optimization when scenario probabilities are not available. It minimizes the maximum value of objective function across all scenarios. In order to assess the performance of the proposed MIP robust model, the following section presents an illustrative example in which the performance of the MIP robust model would be compared versus the Min-Max approach.

5. Numerical Results

We consider the supply chain associated with a product whose lifecycle lasts for six periods. We identify 200 scenarios over the planning horizon with respect to the minor and major disruptions and three levels of capacity losses during the recovery time. We generate scenarios using the scenario tree approach. The demand is assumed to be deterministic and 6,500 units per period. Three different layout configurations are presented as decision variables: parallel, parallel-serial and serial. The parallel configuration provides higher level of capacity during the recovery time however the better scalability increases the investment cost of parallel configuration (Wang & Koren, 2012) as indicated in Table 1.

Table 1: Cost Parameters

Cost	Value	Cost	Value
Parallel investment	135,000	Holding cost ($/unit)	40
Parallel-serial investment	90,000	Back-up supplier production ($/unit)	125
Serial investment	45,000	Main supplier production ($/unit)	25
Strategic stock investment ($/unit)	180	Shortage ($/unit)	300
		Capacity addition ($/unit)	20

The maximum capacity of the main supplier is higher than back-up supplier. These values are set to 10,000 and 7,500 units respectively. The fractions of the added capacity which are available during the recovery time $U_{j,i}$ with respect to the back-up supplier machine configuration and the level of capacity loss are presented in Table 2. Furthermore, we assume the intensity of the minor disruptions on the main supplier results in 30% loss in its maximum capacity.

Based on the stated assumptions and inputs, the following experiments are conducted. First, we evaluate the performance of MIP clustering model which was presented in section 4.1 versus the clustering algorithm in Matlab. This comparison would enable us to investigate the grouping capability of MIP clustering model and its accuracy in identifying cluster centers versus clustering algorithm in Matlab. Eventually, the results show which method has the capability to provide a reduced scenario set closer to the original scenario set. Next, we assess the performance of the proposed MIP robust model versus the Min-Max approach. We evaluate these two methods based on minimizing the average relative regret and the maximum relative regret across all scenarios.

Table 2: Fraction of the added available capacity available during recovery time

Level of capacity loss during recovery	Back-up supplier machine configuration		
	Parallel	Parallel-serial	Serial
High	0.933	0.867	0.8
Normal	0.833	0.667	0.5
Low	0.733	0.467	0.2

5.1 MIP Clustering versus Matlab Clustering

The performance of MIP clustering and Matlab clustering is evaluated by monitoring the output of the MIP robust model. First, we run the MIP robust model by considering all scenarios in the original scenario set Ω and we record the value of the objective function (23) represented by ζ_{Ω}. Second, we execute the MIP clustering model in order to achieve the reduced scenario set N where $N \in \Omega$. Third, we run the MIP robust model by considering the reduced scenario set N and we record the value of the objective function ζ_N. We will also repeat the third step for the reduced scenario set achieved by using Matlab clustering algorithm. Finally, we measure the difference between the objective function of the MIP robust model achieved by considering all scenarios ζ_{Ω} and the reduced scenario set ζ_N based on the following formula.

$$\Pi = \frac{\zeta_{All} - \zeta_N}{\zeta_{All}} \tag{28}$$

The metric Π indicates how close the solution of the MIP robust model considering reduced scenario set is to the case when all scenarios are considered. In order to compare the performance of the MIP clustering versus Matlab clustering, we calculate the metric Π for different size of reduced scenario set N represented in Figure 2.

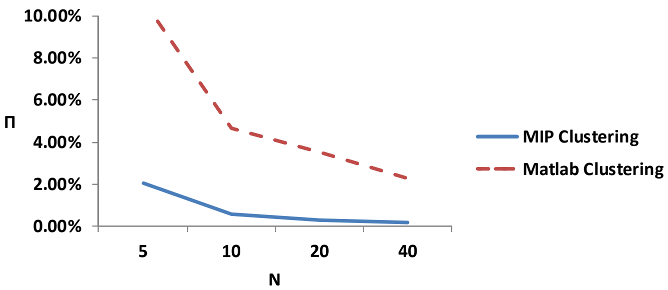

Figure 2: Accuracy of MIP clustering model VS Matlab clustering

For $N = 5$, the value of Π in MIP clustering and Matlab clustering are 2% and 10% respectively. On the other hand, this value decreases to almost 0.15% in MIP clustering and 2.4% in Matlab clustering when N increases to 40. These results indicate that the accuracy of both approaches increase as the size of reduced scenario set increases, however the MIP clustering has a better performance in providing a good approximation of the original scenario set compared to Matlab clustering. In addition to these, the accuracy of the MIP clustering is significantly better than Matlab clustering when the size of reduced scenario set is small. This indicates that the MIP clustering has the capability to provide a reduced scenario with high similarity to original scenario set.

5.2 MIP Robust Model versus Min-Max

In order to compare the performance of the MIP robust model versus Min-Max approach, first we execute the MIP robust model presented in section 4.3. In order to convert the MIP robust in to a Min-Max model, we replace the objective function of the MIP robust model (23) and the constraint (24) with (29) and (30) respectively. Next we execute the following Min-Max robust model.

$$Min\ \mathrm{X} \tag{29}$$

Subject to:

$$\mathrm{X} \geq f_s \quad \forall l,\ \forall s \in S \tag{30}$$

$$(25)\ to\ (27) \quad \forall s \in S \tag{31}$$

The selections of the back-up supplier machine configuration and the initial level of strategic stock using MIP robust model and Min-Max model are Parallel, 225 units and Parallel, 300 units respectively. Although both models select the parallel configuration as the optimal machine configuration of the back-up supplier, the Min-Max model choose a higher level of strategic stock since it only considers the worst case scenario. For the aforementioned solutions, we compute the average and the maximum of relative regret across all scenarios which are presented in Figure 3.

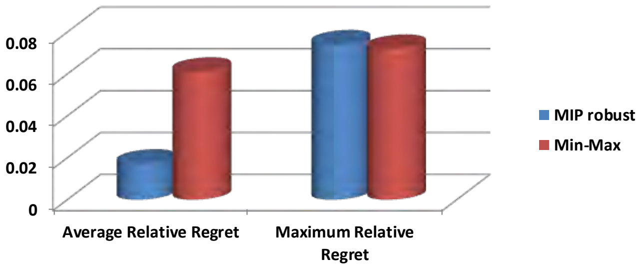

Figure 3: MIP robust model VS Min-Max model

The average of relative regret in MIP robust model is significantly lower than the Min-Max model. This happens since the MIP robust model considers all scenarios and it tries to make the relative regrets to become close to each other as much as possible. Therefore, the MIP robust model provides solutions with higher level of solution robustness compared to Min-Max model. Although the Min-Max model focuses only on the worst case scenario, the maximum relative regret of the MIP robust model is slightly higher than Min-Max model. Therefore, it could be concluded that the MIP robust model has also a reasonable performance in minimizing the maximum of relative regret.

6. Conclusion

In this paper, we evaluate the selection of the strategic stock level and the response speed of the back-up supplier in order to create a robust supply flow under the operational risks and disruption of suppliers. Since it might be difficult to estimate the probability of supplier's disruptions, we try to achieve solution robustness such that the optimal solution would be close to the optimal solution of any scenario as much as possible. To this end, we employ the Ordered Weighted Averaging (OWA) aggregation operator in the objective function of our multi-stage robust optimization model. The results show that the proposed OWA based robust formulation has a reasonable performance in minimizing both the overall relative regret as well as maximum relative regret across all scenarios.

Our problem includes a large scenario set which results in computational complexity. To solve this challenge, we propose a clustering based MIP scenario reduction model. The results indicate that the proposed scenario reduction model has a better performance compared to Matlab clustering function especially when the desired size of reduced scenario set is small. The proposed scenario reduction model is based on solving MIP problem which may become computationally intractable as the number of scenarios gets too large. In a subsequent work, we will develop a heuristic method in order to solve the clustering based scenario reduction model in a reasonable computation time.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Fire Scheduling Problem with Probability of Hit Time Window

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Abstract

In this paper, the fire scheduling problem for air defense systems is examined to plan fire operations at moving targets with a given set of weapon systems by considering hit probabilities. In air defense operation, enemy units are engaged by firepower units in real-time combat situations. A weapon system consists of more than one firepower units with probability of hit which is applicable within a time window. Firepower units on the specific weapon system are activated according to the preceding constraint. This problem is more complex than the classical weapon-target allocation problem by its structure and scheduling requirement. Bi-objective nonlinear mixed integer programming model is formulated and pareto optimal points are shown for a sample problem instance.

Keywords

Weapon-Target Assignment, Fire Scheduling, Probability of Hit, Time Window, Nonlinear Mixed Integer Programming.

1. Introduction

Air defense in a warfare environment aims to defend the assets by using weapons against the detected threats. Assets without self-defense capability may be in different types such as command and control centers, communication centers, radars, arsenal depots. While threats are generally fighter jets flying at very high speeds, field artillery units friendly fighter jets, and missiles are considered as anti-aircraft weapons.

Weapon-target assignment (WTA) problem is a well-known specific case of the more general resource allocation problem in air defense related applications, which determines an optimal assignment of defensive weapons to identified offensive targets such that overall expected effect is maximized, which can be depicted as Fig. 1. Assets usually differ in terms of importance. Thus, while some assets are critical in value and to be protected better, others may not be cared as much. Weapons are not dedicated to defending a specific asset. They can engage any threat if the engagement is feasible. Weapons can also be defined as assets. Number of weapon unit and target are not necessarily equal to each other.

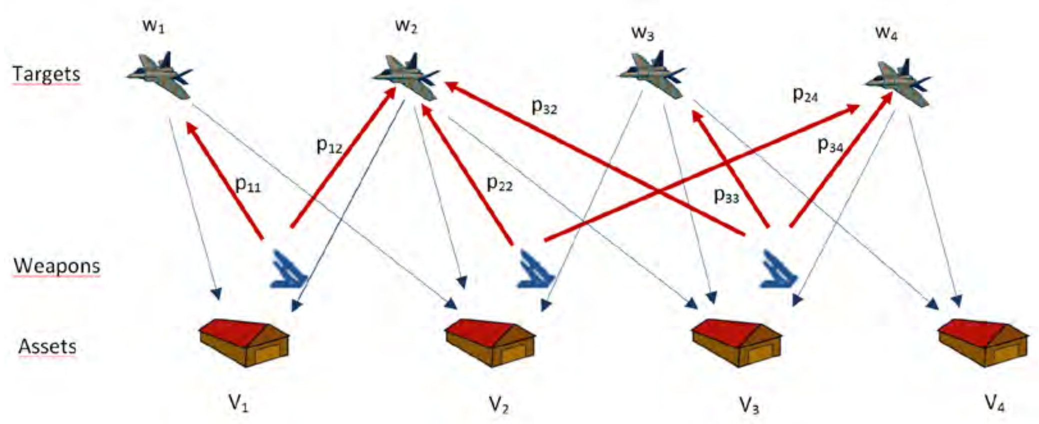


Figure 1: Weapon Target Assignment

Weapon target assignment (WTA) problems have been studied in numerous works. Interested readers can refer to [Cai et al., 2006; Karasakal, 2011; Murphey, 1999; Roux, & Van Vuuren, 2007] for a comprehensive literature review of WTA. In general, there are two versions of the WTA problem, namely: static WTA (SWTA) (Hosein & Athans, 1990a] and dynamic WTA (DWTA) [Hosein & Athans, 1990b]. In SWTA, all weapons engage targets at a single stage, and decision makers know all parameters (i.e., weapons, targets, desired effects, engagement time, etc.) of the problem. Thus, the goal of solving the SWTA problem is to find the optimal assignment for a temporary defense task. In contrast, DWTA is a multistage problem that weapons are assigned to threats in stages based on the damage assessments of previous stages. There is limited time to observe, decide and act; the problem must be solved in a short period of time. Most of the previous researches on WTA focus on SWTA [Xin, & Chen, 2011].

The WTA problem which is formulated as a non-linear integer programming problem, is known to be a typical NP complete problem [Lloyd & Witsenhausen, 1986]. In the literature two types objective functions are used, namely 1) “asset based” i.e. total expected survival value of assets to be maximized, and 2) “target based” i.e. the total expected lethality value of the targets to be minimized [Malcolm, 2004]. Some WTA models also take into account the cost of weapons. For example, Kwon et al. (2007) employed the overall firing cost as the objective function for optimization.

Despite most researches mainly focused on the WTA problem, very few researches exist on the FSP. First introduced the FSP, Kwon et al. (2007) consider the FSP with the objective of minimizing makespan under the assumption that the targets are fixed (not moving). Kim and Lee [2003] combined the fire target allocation problem and sequencing problem in one algorithm and suggest a heuristic approach. Gulez [2007] formulated a nonlinear mathematical model to maximize sum of the weighted survival probabilities of assets to be defended and developed heuristic approaches for surface-to-air weapon-target allocation problem with time varying single shot hit probabilities against linearly approaching threats. His model decides on which weapon-target engagement, number of firing rounds at each threat, and firing time of these rounds. He considered the ammunition availability and the number of engagement opportunities. He assumed that hit probabilities are constant in each round. Cha and Kim [2010] assumed that weapon-target assignments are given, and the probability that a moving target is destroyed by a firing attack declines due to aircraft protection systems. They used objective of minimizing total threat of the targets, which is expressed as a function of the destruction probabilities of the targets. It is assumed that the destruction probability decreases linearly as time passes. The targets are movable and able to hide themselves from anticipated attack by a situation awareness system. The target-weapon allocation is given. Firing operations against targets assigned to more than one weapon, such as multiple-weapon targets, should be started simultaneously from the weapons. Cha and Bang [2015] proposed a branch and bound algorithm to determine the sequence of targets to be fired at, for the objective of minimizing makespan to achieve tactical goals.

In this paper, we mainly focus on the static fire scheduling problem which aims to find optimal sequence of fires at a specific weapon in terms of two objectives: 1) maximizing sum of the weighted survival probabilities of assets and 2) minimizing the total weapon cost with balanced utilization. In the SFSP, firing unit-target assignment, and firing scheduling are achieved simultaneously for a single decision making stage in a dynamic warfare environment consists of multiple stages. Moreover, firing time window between earliest and latest time is defined for each firing unit that a non-zero expected probability of hit is applicable.

In the following section, problem details are described. A nonlinear mixed integer programming model formulation is presented for the problem in Section 3 and tradeoff between defense effect and cost objectives is analyzed for a sample problem instance in Section 4.

2. Problem Definition

Static fire scheduling problem mainly considers the field artillery units which have capability of multiple subsequent firing. A weapon system can use multiple units to attack a target. Since maximum number of firing operation is known beforehand, each firing unit has been considered as a separated weapon of which firing time depends on the preceding fires.

Three parameters related to elements of the problem are the value of assets(Vj), the lethality values of the target-asset pairs(w_{jk}) and the hit probability of the weapon-target pairs(p_{ik}). The lethality value indicates how lethal the target is to the asset if it survives to its destination. This depends on risk value of the asset for the warfare, as well as the type, location (range, sector), velocity, and course of the target. The killing asset probability of a threat the asset is assumed constant. A threat can attack one or more assets in a given scenario.

Moreover, single shot probability of hit for a single weapon varies by time depending on the distance between weapon and target, speed and direction of the target. Note that, a target can be assigned to more than one firing unit. The set of assigned firing units should start firing at the target such that probability of hit is maximized. The probability of kill is the weapon's probability of destroying the target if engaged. Probability of hit depends on all aspects of engagement, such as the type of weapon and the type, role in the warfare, altitude, distance, linear direction, speed, and ammunition payload of the target aircraft.

SFSP can be depicted as Fig. 2. Fire scheduling refers to deciding fire–target assignments, determining fire occurring times and ammunition amount of each fire. Firing operations cannot be assigned to more than one target. Despite first two fire operations are assigned to the first and second targets respectively, the third fire unit remained unoperated due to ammunition cost and firing time window constraint.

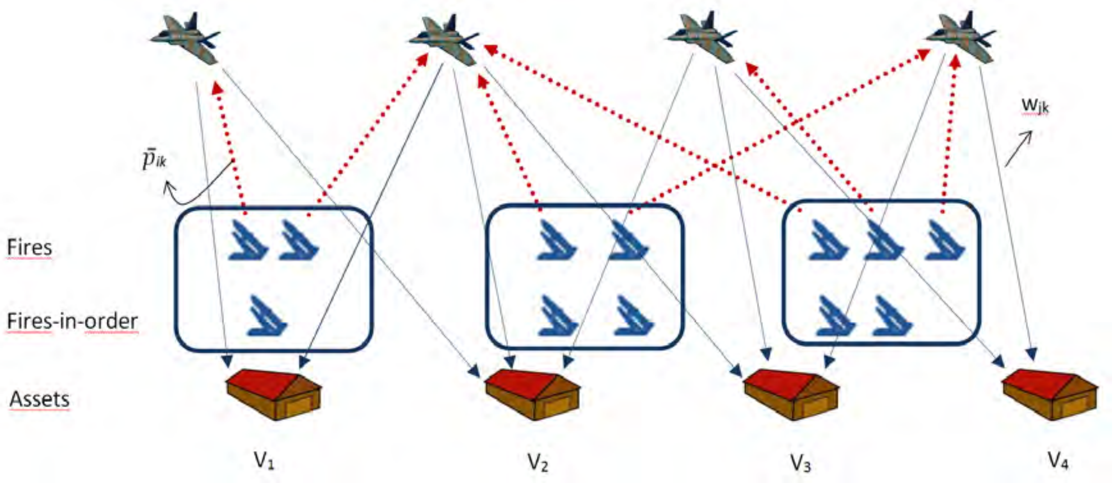


Figure 2: Fire Scheduling

In this research, weapons have variable single shot hit probabilities based on the position of the threat. Since velocities of threats are invariant during the attack and weapons are immobile, these probabilities change in time as the threat moves. We assumed weapons have specific minimum and maximum target ranges. Consequently, hit probability time window for each firepower unit-target pair are defined as depicted in Fig. 3.

In this study, to establish reasonable mathematical model formulation for the FSP, the following assumptions can be defined as:

- Number of weapon unit and target are not necessarily equal to each other.
- Threats make linear movement and their velocity does not change during the attack.
- The information on targets such as locations, sizes, velocities and also min./max. hit probabilities of fire unit-target pairs and the earliest and latest times are known in advance.
- Each fire unit can fire at most one target.
- Firing processing times are given and proportional to the amount of sequentially launching ammunitions.
- Firing setup time includes loading ammunition, turning the muzzle, watching and tracking the threat, and engaging and firing.
- Preemption of a job is not allowed.
- The communication system supply location information correctly without any delay.

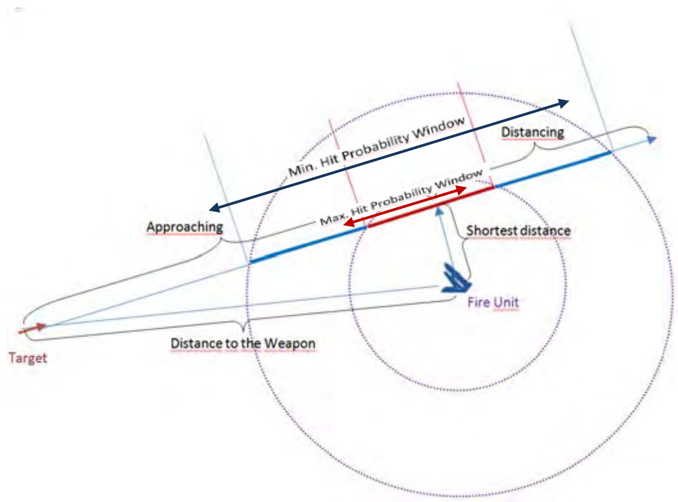


Figure 3: Hit Probability Time Window

3. Mathematical Model Formulation

We aimed to develop a mathematical formulation to maximize the weighted sum of the survival probabilities of assets and to minimize the total weapon cost with balanced utilization. The weights reflect the value or importance of assets. The asset based mathematical model formulation involves desired success, time window, capability, resource capacity, preceding constraints. To formulate the weapon-target assignment problem, we use the following notation and variables.

Sets:

I: fires (i= 1….I),

K : targets (k=1….K),

A: assets (j=1…A),

W: weapons (w=1…W), $I = \{I_w : \mathrm{w} = 1 \ldots \mathrm{W}\}$

Parameters

w_{jk} – the threat value of target k for asset j. This is determined as a result of threat evaluation to use as a priority in target engagement.

V_j – value of the asset j,

S_k – the minimum expected damage success to target k,

r_i – ready time of the fire i, indicating an extension of the preceding engagement in the previous stage

K_i – maximum number of missiles to launch during a fire, batch size of the fire i,

m_{ik}– time interval between subsequent missile launches in fire i to target k,

s_i– engagement time of fire i, indicating weapon dependent setup time for a new engagement,

C_l – the total number of missiles available on weapon l, indicating munitions capacity of the weapon,

I_l – number of missiles used for the preceding engagement in the previous stage,

T – the latest time(deadline) to start engagement, indicating time horizon for each static stage,

t_{min} – minimum probability of hit within range time window,

t_{max} – minimum probability of hit within range time window,

$\bar{P}_{ik}$ – average hit probability of the fire i to target k at time t,

M –a large integer.

Decision Variables

X_{ik} – an binary decision variable indicating fire i assigned to target j, 1 assigned, 0 ow.

d_{ik} – an integer decision variable indicating the number of missiles of fire i assigned to target j.

t_{ik} – engagement starting time of fire i to target j.

In FSP, one of the objective functions is total expected weighted asset defense value. Eq.1 denotes the threat probability of target k for the asset j meaning that weighted survival probability from fires assigned to it.

$$\omega_{jk} \prod_{i}^{M} (1 - \bar{P}_{ik})^{d_{ik}} \qquad (1)$$

Eq. 2 indicates overall probability of destroying targets for an asset such that higher valued (more threating) targets for an asset should be destroyed by a higher probability.

$$\prod_{k}^{T} \left(1 - \omega_{jk} \prod_{i}^{M} (1 - \bar{P}_{ik})^{d_{ik}}\right) \qquad (2)$$

NLMIP Model for FSP

$$\max Z_1 = \sum_{j}^{A} V_j \prod_{k}^{T} \left(1 - \omega_{jk} \prod_{i}^{M} (1 - \bar{P}_{ik})^{d_{ik}}\right) \qquad (3a)$$

$$min\ Z_2 = \left(\sum_{i}^{I} \sum_{k}^{K} d_{ik}\right) . \max_{w} \left(\frac{\sum_{i \in I_W, k \in K} d_{ik}}{C_w}\right) \qquad (3b)$$

$$1 - \prod_{i}^{I} (1 - \bar{P}_{ik})^{d_{ik}} \geq S_k \quad \forall k \in K \qquad (4)$$

$$\sum_{k}^{K} X_{ik} \leq 1 \quad \forall i \in I \qquad (5)$$

$$t_{ik} \geq \max(r_i, t_{min}).X_{ik} \quad \forall i \in I, \forall k \in K \qquad (6a)$$

$$t_{ik} \leq min(T, t_{max}).X_{ik} \quad \forall i \in I, \forall k \in K \qquad (6b)$$

$$d_{ik} \leq K_i.X_{ik} \quad \forall i \in I, \forall k \in K \qquad (7a)$$

$$d_{ik} \geq X_{ik} \quad \forall i \in I, \forall k \in K \qquad (7b)$$

$$\sum_{i \in I_W, k \in K} d_{ik} \leq C_w - I_w \quad \forall w \in W \qquad (8)$$

$$\sum_{k}^{K} X_{(i+1)k} - \sum_{k}^{K} X_{ik} \leq 0 \quad \forall i \in I_W, \forall w \in W \qquad (9a)$$

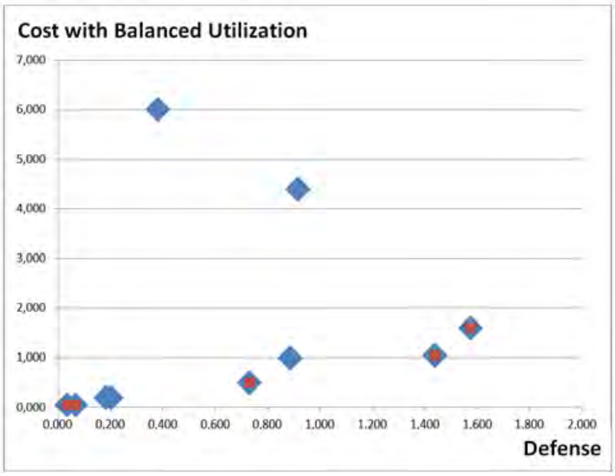
$$\sum_{k}^{K} t_{(i+1)k} + M\left(1 - \sum_{k}^{K} X_{(i+1)k}\right) \geq \sum_{k}^{K} t_{ik} + \sum_{k}^{K} m_{ik}.d_{ik} + \sum_{k}^{K} s_i.X_{(i+1)k} \quad \forall i \in I_W, \forall w \in W \qquad (9b)$$

$$d_{ik} \in Z^+, t_{ik} \geq 0;\ X_{ik} \in \{0,1\} \quad \forall i \in I, \forall k \in K \qquad (10)$$

Eq. 3a denotes the total expected weighted asset defense value which provides to concentrate on destroying the targets aimed at high-value assets. Eq. 3a denotes the second objective function which indicates the firing cost with balanced weapon utilization. Eq. 4 guarantees desired success level in destroying a specific target. In Eq.5, a single fire cannot be assigned to more than one target. Eq.6 a-b defines fire scheduling time window. According to Eq.7a-b, fire size cannot exceed sequential firing capability. Eq. 8 provides weapon capacity constraint that distributed unit total of each type weapon cannot exceed the number of assigned weapon unit resources in the warfare time. Eq. 9 a-b indicates subsequent fire assignments preceding constraints. Finally, Eq.10 describe decision variables.

4. Computational Study

Bi-objective nonlinear mixed integer programming model was implemented by GAMS IDE for a sample problem instance. Details of the sample instance are given in Tables 3-7. This problem have elements with count of A=3, K=5, W=3, I=7. Weapon capacity and inventory values are as follows C_1=C_2= 50, C_3 =20, I_1=I_3=1, I_2=0. Pareto optimal points with respect to various objective priority values (λ), where scalar objective is formulated by $Z= \lambda.Z_1+ (1- \lambda).Z_2$, are shown in Fig. 4.



λ	Defense	Cost
0,9	0,381	6,000
0,8	1,574	1,600
0,7	0,916	4,400
0,6	1,437	1,050
0,5	0,729	0,500
0,4	0,886	1,000
0,3	0,034	0,050
0,2	0,203	0,200
0,1	0,182	0,200

Figure 4: Pareto Optimal Values

Optimal fire assignments, amount of ammunitions and scheduling time of assigned fires in terms of a single objective, are given in Table 1-2. The model maximizing air defense value results in air defense and cost with balanced utilization values as (1.95, 33.3). Utilization ratios for three weapons are (0.85, 0.9, 0.2), respectively. The model minimizing cost with balanced utilization value gives air defense and cost with balanced utilization values as (1.547, 1.600). Utilization ratios for three weapons are (0.2, 0.1, 0.2), respectively.

Table 1: Fire Scheduling with (d_{ik},t_{ik}) (Max. Air Defense)

	1	2	3	4	5
1				(5,10)	
2					
(6,22)					
3			(6,36)		
4		(9,27)			
5	(9,48)				
6			(1,12)		
7			(1,14)		

Table 2: Fire Scheduling with (d_{ik},t_{ik}) (Min. Cost with balanced utilization)

	1	2	3	4	5
1			(2,30)		
2				(1,36)	
4		(1,7)			
5					
(2,12)					
6	(1,12)				
7	(1,14)				

5. Conclusion

In this research, we considered the original fire scheduling problem with hit probability hit time windows. Bi-objective nonlinear mixed integer programming model is formulated and pareto optimal points are found for a sample problem instance. Computational study shows that the model is effective to find optimal solutions in terms of defense and cost objectives. In future works, mathematical model formulation may be improved to contain realistic issues, new solution methods can be developed and extensive experiments need to be conducted to present the effectiveness of the solution methods.

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Biography

Sezgin Kaplan is Assistant Professor at Turkish Air Force Academy in the Department of Industrial Engineering. He received the B.S. degree in industrial engineering in 2000 from Bilkent University, Turkey, the M.A. degree in Economics from Hacettepe University, Turkey in 2004, the M.S. degree in Industrial engineering from Gazi University, Turkey in 2007 and the Ph.D. in Engineering Management from Old Dominion University, VA, USA in 2011. He followed the post doc program in the Department of Industrial and Systems Engineering at Georgia Institute of Technology, GA, USA His teaching and research interests include operations research, planning and scheduling, applied optimization, logistic systems management.

Problem Instance

Table 3: Threat, asset and success values

w_{jk}	1	2	3	4	5	V_j
1	.42	.53	.65	.53	.92	11
2	.46	.56	.72	.26	.89	13
3	.42	.66	.64	.41	.74	15
S_k	.90	.90	.90	.90	.90	

Table 4: Processing time per ammunition

m_{ik} type	1	2	3	4	5	weapon
1	2	2	2	2	2	1
2	2	2	2	2	2	1
3	2	2	2	2	2	1
4	2	2	2	2	2	2
5	2	2	2	2	2	2
6	1	1	1	1	1	3
7	1	1	1	1	1	3

Table 5: Firepower unit values

1	2	3	4	5	6	7
s_i 1	0	2	2	0	3	0
K_i 1	6	6	6	9	9	1
r_i 5	10	10	10	0	0	5

Table 6: Probability of Hit

p_{ik} 5	1	2	3	4
1 .80	.70	.75	.70	.95

2	.70	.75	.70	.95	.80
3	.70	.75	.70	.95	.80
4	.70	.90	.70	.80	.70
5	.70	.90	.70	.80	.70
6	.85	.90	.85	.70	.70
7	.85	.90	.85	.70	.70

Table 7: Time window values

$(t_{ik}^{min}, t_{ik}^{max})$	1	2	3	4	5
1	(45,60)	(30,51)	(30, 36)	(9,36)	(15,36)
2	(45,60)	(30,51)	(30, 36)	(9,36)	(15,36)
3	(45,60)	(30,51)	(30, 36)	(9,36)	(15,36)
4	(48,60)	(6,42)	(36,42)	(18,36)	(12,30)
5	(48,60)	(6,42)	(36,42)	(18,36)	(12,30)
6	(12,54)	(32,60)	(12,33)	(6,18)	(32,60)
7	(12,54)	(32,60)	(12,33)	(6,18)	(32,60)

Simulation based optimization of stock levels for maintenance logistics with multi-skill parallel servers

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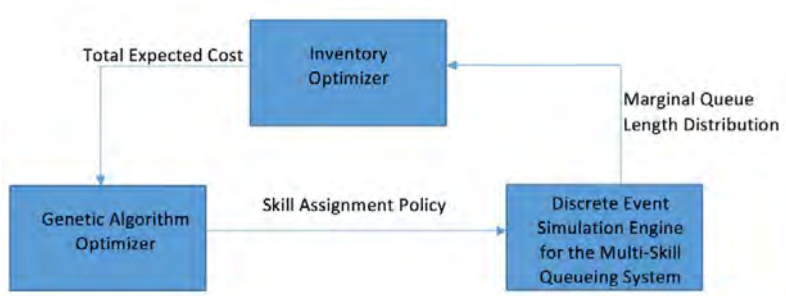
Downtime of advanced technical equipment is inevitable. Nevertheless, it can be reduced by preventive maintenance activities such as condition based monitoring or immediate replacement of malfunctioned parts/ components by ready-for-use spares. In this study, we focus on the latter by analyzing a multi-skilled parallel server system consisting of one repair shop and one stock point, where spare parts of multiple, critical repairables are kept on stock to serve an installed base of technical systems. In the system, the failed spare parts are immediately replaced from inventory if possible. In case of unavailability, failed parts are backordered and fulfilled when a ready-for-use part becomes available. In other words, one of the same type already failed spare part get fixed in the repair shop. Repair shops usually handle several types of repairables, but it is not possible or cost effective to have every server be able to handle every type of repairable. Thus, servers have different combination of skills. In such an environment, design of repair shop becomes a challenging problem.

The aim of this research is to study the effect of multi-skilled servers and repair shop design on the total system performance. In this direction, the proposed mathematical optimization model tries to minimize total expected cost of holding inventory of spare parts, backorder cost arising from downtime of system due to the lack of spare parts and cost of having multi-skilled servers that have ability of repair different types of spares.

As a solution strategy, simulation based metaheuristic algorithm is proposed to overcome the mathematically intractable structure of the model. Figure 1 depicts the flowchart of methodology. In the methodology, Genetic Algorithm (GA) is utilized as primary metaheuristic tool to find the optimal skill assignment of servers. In each iteration of the algorithm, GA generates a set of feasible solutions for skill assignment problem. Afterwards, the solutions are used as input of discrete event simulation (DES) engine. DES basically mimics the behavior of the parallel multi-skill servers queuing system with dedicated queues for each repairable. The steady state queue length probability distributions for each type of repairable are obtained at the end of every simulation run. Then second stage of optimization is taken place, in which optimal safety inventory levels for each repairable are calculated by marginal analysis technique. Marginal analysis is applicable due to the separable structure of objective function for each spare part. Each sub-problem can be solved optimally because of their news-vendor type objective function structure. Inventory optimization sub-routine also calculates expected backorder and expected holding costs, and feeds total cost to GA engine till predefined iteration number is reached.

In order to show efficiency of methodology, the algorithm performance is tested by altering number of servers, number of repairable types, failure rates and service rates. The promising results are obtained in terms of tight gaps between objective values of brute-force enumeration and proposed algorithm. In addition to the computational results, managerial insight about the behavior of the system under optimal conditions are provided.

Figure 1. The proposed discrete event simulation based two-stage heuristic algorithm.



Acknowledgements

This publication was made possible by the NPRP award [NPRP 7-308- 2-128] from the Qatar National Research Fund (a member of The Qatar Foundation).

Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Minimizing Total Earliness Subject to Minimum Number of Cells and n_T=0

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Abstract

This paper focuses on cell loading in a cellular manufacturing environment. There are various performance measures considered in this study including number of tardy jobs, minimizing number of manufacturing cells and minimizing total earliness. As meeting customer due dates are of vital importance in any manufacturing company, the primary performance measure is to have zero number of tardy jobs (n_T). Obviously, cells consist of several machines and workers and require significant investment. Therefore, manufacturing companies avoid opening cells unless they are needed. Here, the secondary performance measure is to minimize the number of cells (c_{min}) that will guarantee n_T=0. In classical scheduling, most procedures schedule the jobs as early as possible. However, this increases earliness and hence leads to finished goods inventory. In this paper, the third performance measure is to minimize total earliness (TE). A two-phase approach is used to tackle this problem. In the first phase, a mathematical model is proposed to minimize number of cells subject to zero of tardy job requirement. Having determined the minimum number of cells, in the second phase another mathematical model is proposed where total earliness is minimized while keeping number of tardy jobs zero. An example problem is solved to illustrate the proposed methodology and then results of experimentation are reported.

Keywords

Cell loading, cell scheduling, mathematical modeling

1. Introduction

A cellular manufacturing system (CMS) is usually designed to produce products that have moderate variety and moderate demand. In cellular systems, products are grouped into families and each family is produced in a machine group called cell. As a result, a cell usually consists of distinct machines needed to produce the assigned product family. The claimed benefits of cellular systems are lower number of setups and hence smaller lot sizes, lower work-in-process inventory levels, shorter leadtime, reduced material handling (Suresh and Kay, 1998). Cell Loading deals with allocation of products/product families to cells in a multi-cell environment. This allocation is done considering demand, processing times and due dates of the products as well as the feasibility and capacity of the cells (Süer et al., 1995, 1999). In a complex cellular system, there are various tasks to be performed when it comes to control aspects and these include, at the higher level, family loading, family sequencing, family scheduling and at the lower level, cell loading, cell scheduling, manpower scheduling, operator assignment to cells, operator assignment to operations/machines. In many cellular systems, ideally unit piece flow strategy is adapted to reduce work-in-process inventory and also to lower leadtime. In such a flow system, the bottleneck machine becomes the focus and dictates the production rate to be obtained from the cell (Egilmez and Süer, 2013).

In manufacturing systems, capacity determination and machine scheduling are among the critical tasks. In most systems, first capacity requirements are determined and then detailed machine scheduling is performed to fit into the determined machine levels. In cellular environments, the capacity planning establishes the number of cells needed. On the other hand, scheduling establishes start and completion times of jobs on cells. In cellular systems, there is an important relation between number of cells and scheduling performance measures to be adapted. Obviously, the higher the number of cells, the better the scheduling performance measures will be. On the other, underutilized cells also costs to the company. In this paper, an attempt is made to handle these two issues simultaneously. In other words, we consider determining minimum number of cells as one of the objectives of the paper. As to scheduling performance measures, we consider both number of tardy jobs and total earliness. A job is called tardy if its completion time is greater than its due date ($c_i > d_i$) where c_i is the completion time of job *(i)* and d_i is the due date of job *(i)*. Earliness for a product takes a value of zero or positive, $E_i = max\ \{0, di - ci\}$; where E_i is the earliness for product *(i)*. In any manufacturing company, tardy jobs are never desirable. Companies may have to rush orders to avoid jobs reaching customers late, or agree to pay late fees, etc. It adversely affects company's reputation and in the long run it may result in lost sales. Earliness is not desirable either, as it implies increased costly inventory levels. Earliness is also very critical in industries where product is perishable and/or has limited shelf life. A product sitting in the warehouse before it reaches to the customer reduces shelf life of the product in the market and hence increases the chance that it may not be sold by the recommended date. Customers will not allow such risks for themselves.

In this study, a two-phase approach is proposed to minimize number of cells that will result in zero tardiness (i.e. zero tardy jobs) and also minimize total earliness subject to minimum number of cells. Mathematical models are proposed to accomplish these goals in both phases. Section 2 discusses relevant literature review. Section 3 introduces the overall proposed methodology. Mathematical models for phases 1 and 2 are discussed in Sections 4 and 5, respectively. An example is given in Section 6 and results and conclusions are given in Section 7.

2 Literature review

In cell loading, first production rates are determined based on the routes and processing times information and then cell loading and job sequencing tasks are performed (Süer, 1997). Greene and Sadowski (1983) discussed the advantages and advantages of utilizing CM systems. Süer (1997) developed two mixed integer mathematical models to minimize the number of tardy jobs in a multi-period cellular environment. Süer et al. (1995, 1999) presented several simple manufacturing cell loading rules for connected and independent cells to deal with performance measures n_T, TT, T_{max} and cell utilization. Süer et al. (2005a) developed a hybrid approach of Genetic Algorithms and local optimizer to minimize number of tardy jobs in a multi-cell environment. Süer et al. (2013) proposed mathematical optimization to minimize the total tardiness in labor intensive manufacturing cells.

In another work, Süer and Bera (1998) developed an approach which simultaneously performs the cell loading and cell size determination in a labor intensive manufacturing system. Fuzzy mathematical approaches have been also developed for cell loading subject to manpower level restrictions in Süer et al. (2008, 2009a). Additionally, integrated cellular design and control problem has also been recently addressed in the presence of probabilistic processing times and product demand (Egilmez and Süer, 2013).

There are also a few works that address performs cell loading and product sequencing tasks simultaneously. Süer and Dagli (2005b) and Süer et al. (2009b) discussed models to minimize makespan, machine requirements and manpower transfers. Yarimoğlu (2009) developed a math model and genetic algorithm (GA) to minimize manpower shortages in synchronized manufacturing cells. The most recent work addressed a stochastic mathematical optimization model for a set of cell loading and job scheduling problems in a single period environment (Egilmez and Süer, 2015).

Mathur and Süer (2013) used mathematical modeling and GA for scheduling in a textile manufacturing facility considering overtime. The objective was profit maximization by minimizing the number of tardy jobs using overtime. The results showed that mathematical modeling approach was more effective than GA in most cases.

Related to the works that focus on scheduling jobs on the rotary injection molding machines in shoe manufacturing industry, Süer et al. (2009c) extended the problem with some heuristic procedures and MMs. Huang et al. (2012) proposed a sequential GA model for rotary machine scheduling considering sequence dependent processing and setup times. Mese's MM and a GA are comparatively experimented on various problem sizes considering single and hybrid objectives, job splitting and common due date scenarios to increase the overall understanding about the group scheduling problem in a cellular shop.

3. The General Methodology Used

This paper uses a 2-phase approach to deal with all three objectives;

Phase 1. Determining minimum number of cells (c_{min}) to have zero tardy jobs (n_T=0)
Phase 2. Minimizing total earliness (TE) subject to (c_{min}) and (n_T=0)

A mathematical modeling formulation has been developed in each phase to tackle the problem. These models are solved using CPLEX software.

3.1 Phase 1 – Determining minimum number of cells

As mentioned in previous sections, in practice, one of the most important considerations is to create a schedule for all jobs with no tardiness. In this section, a mathematical model is developed to determine the minimum number cells considering job processing times and due dates. As it will be shown in the example problem later, it is evident that the jobs can be completed with less capacity than provided. In most scheduling literature, it is assumed that resources are fixed and jobs are scheduled around it. However in this paper, both capacity decisions and scheduling decisions are made simultaneously. Obviously, this is a more complicated but a better approach. Some of the basic assumptions made in this paper can be summarized as each job can be assigned to only one cell and cells are identical.

3.2 Phase 2 – Schedule generation to minimize total earliness

Having determined the minimum number of cells to have zero tardy jobs in the first phase, the second phase starts to re-schedule jobs such that now total earliness is minimized while keeping all jobs on time or early. Minimizing earliness is very desirable in just-in-time environments. This is important as it implies lower inventory levels. In perishable goods industries, this has increased significance. This also helps to maintain near perfect shelf-life for products in industries such as food and pharmaceutical products. It is not unusual to see some resources idle when these two phases are implemented. In these cases, it is expected that management will transfer workers to the areas where they can be used.

4. Mathematical model for phase 1

The objective of this integer programming model is to minimize the number of cells (c_{min}) opened to complete a given set of jobs with given processing times and due dates. The objective function is to the minimize number of cells as given in equation (1). In equation (2), jobs are forced to be completed by their due dates. Equation (3) ensures that a job is assigned to a cell only if the cell is opened. Finally, equation (4) ensures that each job can only be assigned to one cell. Decision variables take binary values as indicated in equation (5).

Indices:

i	*job index*
j	*cell index*

Parameters:

n	*number of jobs*
l	*number of cells considered in the model*
p_i	*processing time for job i*
d_i	*due date for job i*

Decision variables:

x_{ij}	*1 if job i assigned to cell j, 0 otherwise*
y_j	*1 if cell j is opened, 0 otherwise*

<u>*Objective Function:*</u>

$$\text{Min } c_{min} = \sum_{j=1}^{l} y_j \qquad (1)$$

<u>*Subject to:*</u>

$$\sum_{i=1}^{k} p_i * x_{ij} \leq d_k \qquad k = 1, 2, 3 \ldots n, \quad j = 1, 2, 3 \ldots l \qquad (2)$$

$$x_{ij} \leq y_j \qquad i = 1, 2, 3 \ldots n, \quad j = 1, 2, 3 \ldots l \qquad (3)$$

$$\sum_{j=1}^{l} x_{ij} = 1 \qquad i = 1, 2, 3 \ldots n \qquad (4)$$

$$\text{where } x_{ij}, y_j \in (0,1) \qquad (5)$$

5. Mathematical model for phase 2

In this section, a mixed integer programming model is proposed to minimize total earliness subject to c_{min} and n_T=0. The optimal c_{min} value obtained in Phase 1 is used as input to this model. The proposed model determines the jobs assigned to each cell as well the sequence of jobs in each cell.

The objective function is to minimize the total earliness as given in Equation (6). Equation (6) guarantees that each job is assigned to a position in one of the cells. The completion times of the jobs in the 1st position are computed using Equation (8). Equation (9) establishes the lower bound of completion times of all jobs assigned to 2nd or later positions in all cells. The earliness values for each job are determined by using Equation (10). Equation (11) ensures that tardiness values of jobs are zero, and equation (12) ensures that no more than one job is scheduled to a position.

Indices:

i	*job index*
k	*position index*
j	*cell index*

Parameters:

n	*number of jobs*
c_{min}	*number of cells opened*
p_i	*processing time for job i*
d_i	*due date for job i*

Decision Variables:

x_{ikj}	*1 if job i assigned to position k in cell j, 0 otherwise*
c_{kj}	*completion time of job in position k in cell j*
e_{kj}	*earliness for job in position k in cell j*
t_{kj}	*tardiness for job in position k in cell j*

Objective Function:

$$\text{Min TE} = \sum_{k=1}^{n} \sum_{j=1}^{cmin} e_{kj} \quad (6)$$

Subject to:

$$\sum_{k=1}^{n} \sum_{j=1}^{cmin} x_{ikj} = 1 \qquad i = 1,2,3 \ldots n \quad (7)$$

$$c_{1j} \geq \sum_{i=1}^{n} p_i * x_{i1j} \qquad j = 1,2,3 \ldots c_{min} \quad (8)$$

$$c_{kj} \geq c_{k-1,j} + \sum_{i=1}^{n} p_i * x_{ikj} \qquad j = 1,2,3 \ldots c_{min},\ k = 2,3,4 \ldots n \quad (9)$$

$$c_{kj} - \sum_{i=1}^{n} d_i * x_{ikj} = t_{kj} - e_{kj} \qquad j = 1,2,3 \ldots c_{min},\ k = 1,2,3 \ldots n \quad (10)$$

$$\sum_{k=1}^{n} \sum_{j=1}^{cmin} t_{kj} = 0 \quad (11)$$

$$\sum_{i=1}^{n} xikj \leq 1 \qquad j = 1,2,3 \ldots c_{min},\ k = 1,2,3 \ldots n \quad (12)$$

where $x_{ikj} \in (0,1)$ and $c_{kj}, e_{kj}, t_{kj} \geq 0$.

6. An example

In this section, a small problem is solved to illustrate the methodology. A set of 6 jobs to be scheduled in a system with unknown cells is given in Table 1 along with their processing times and due dates.

Table 1. Data for the Example Problem

	Jobs					
	J1	J2	J3	J4	J5	J6
p_i	6	3	4	10	8	2
d_i	8	10	12	15	16	18

The results for the example problem after solving phase 1 model show that three cells are sufficient to avoid any tardy jobs. J1 is assigned to cell 1, J4 is assigned cell 2 and J2, J3, J5 and J6 are assigned to cell 3. Cell 4 is not opened at all. This means that the phase two model now should be limited to three cells as well. The optimal schedule for phase 1 is shown in Figure 1 (this is one of the alternative optimal solutions) and results are summarized in Table 2 where s_i indicates the start time of job i, c_i the completion time of job i and e_i the earliness of job i. The total earliness value after this phase is 21.

Table 2. Results of phase 1 model for the example problem

Jobs	p_i	s_i	c_i	d_i	e_i
J1	6	0	6	8	2
J2	3	0	3	10	7
J3	4	3	7	12	5
J4	10	0	10	15	5
J5	8	7	15	16	1
J6	2	15	17	18	1

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cell 1	J1																			
Cell 2	J4																			
Cell 3	J2			J3				J5								J6				
Cell 4																				

Figure 1. The Gantt chart for phase 1 optimal solution

After running phase 2 model, the results obtained are given in Table 3. The gantt chart for the optimal solution is given in Figure 2. As seen in Table 3, jobs J1, J3, J4, J5 and J5 are completed just-in-time (with zero earliness) and J2 is completed early by 2 units. One can also observe that start times of jobs are delayed as much as possible without making them tardy. Once again, the objective is to minimize the total earliness with minimum number of cells and zero tardiness.

Table 3. Results of the phase 2 model for the example problem

Jobs	p_i	s_i	c_i	d_i	e_i
J1	6	2	8	8	0
J2	3	5	8	10	2
J3	4	8	12	12	0
J4	10	5	15	15	0
J5	8	8	16	16	0
J6	2	16	18	18	0

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cell 1						J2			J3											
Cell 2						J4														
Cell 3			J1						J5								J6			

Figure 2. The Gantt Chart for the optimal solution

7. Results and Conclusion

To show the effectiveness and robustness of this two-phase methodology, two larger datasets are also tested. The two larger datasets are given multiple due dates to simulate the tradeoff of adding additional capacity to meet all customer needs. The number of jobs in datasets 1 and 2 are 14 and 20, respectively. An initial estimate is made to determine the number of cells to input to phase 1 model. The number of cells opened and corresponding earliness values can be determined by solving the proposed models. In each set, due dates of most jobs increases from D1 to D2 and to D3 randomly. Datasets 1 and 2 are shown below in Tables 4 and 5 with their respective results.

Table 4. The results for dataset 1

Dataset 1										
Job	Processing Times	Job due date (D1)	Job due date (D2)	Job due date (D3)	Job completion time (D1)	Job completion time (D2)	Job completion time (D3)	TE (D1)	TE (D2)	TE (D3)
1	10	15	18	24	14	16	19	1	2	5
2	8	20	22	28	20	19	27	0	3	1
3	5	40	40	40	40	40	40	0	0	0
4	6	14	18	24	9	15	24	5	3	0
5	12	21	25	30	21	21	26	0	4	4
6	11	16	24	27	14	21	18	2	3	9
7	14	22	30	35	22	30	35	0	0	0
8	15	21	27	32	21	27	22	0	0	10
9	9	18	25	31	17	24	21	1	1	10
10	7	15	26	33	12	26	33	3	0	0
11	10	24	34	37	24	34	37	0	0	0
12	15	29	36	40	29	36	40	0	0	0
13	17	34	38	39	34	38	39	0	0	0
14	4	36	40	40	36	40	40	0	0	0

Table 4. The results of dataset 2

Dataset 2										
Job	Processing Times	Job due date (D1)	Job due date (D2)	Job due date (D3)	Job completion time (D1)	Job completion time (D2)	Job completion time (D3)	TE (D1)	TE (D2)	TE (D3)
1	6	12	15	18	12	15	18	0	0	0
2	5	10	12	15	10	12	15	0	0	0
3	4	8	10	12	8	10	12	0	0	0
4	14	28	34	40	28	34	40	0	0	0
5	16	32	36	40	32	36	40	0	0	0
6	20	40	40	40	40	40	40	0	0	0
7	11	22	27	33	20	20	26	2	7	7
8	8	16	20	24	16	20	22	0	0	2
9	9	18	22	27	18	20	26	0	2	1
10	7	14	17	21	14	17	21	0	0	0
11	16	32	36	40	32	36	40	0	0	0
12	18	36	38	40	36	38	40	0	0	0
13	20	40	40	40	40	40	24	0	0	16
14	19	38	39	40	38	39	40	0	0	0
15	15	30	35	40	30	35	40	0	0	0
16	13	26	32	39	26	20	39	0	12	0
17	11	22	27	33	20	20	23	2	7	10
18	10	20	25	30	19	20	25	1	5	5
19	17	34	37	40	34	37	40	0	0	0
20	8	16	20	24	16	20	24	0	0	0

The results of experimentation are summarized in Table 6. It is seen that as the due dates are relaxed, the number of cells needed decreases but the total earliness of the jobs increases. Based on this, once can also study the tradeoff between number of cells and total earliness. Other possible future extensions of this work are modifying models to allow some tardiness values, maximum tardiness values, restricting maximum earliness values, and allowing lot splitting.

Table 6. Summary of Results

	Dataset 1 D1	Dataset 1 D2	Dataset 1 D3	Dataset 2 D1	Dataset 2 D2	Dataset 2 D3
Number of Cells Opened	7	6	5	10	9	8
Total Earliness Value	12	16	39	5	33	41

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A GA Approach for Minimizing Total Manpower Shortage in Synchronized Manufacturing Cells

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Abstract

This paper considers a product-sequencing problem in a synchronized cellular manufacturing environment. This problem has been observed in a jewelry manufacturing company and is valid in other labor-intensive cellular environments as well. Manufacturing process in the cell is divided into (s) stages and work period is divided into (n) time buckets. The products scheduled to be completed in time bucket (t) are processed in stage s in that bucket; processed in stage (s-1) in time bucket (t-1) and so on. The scheduling problem handled has two aspects: first, determining number of workers to be allocated to each stage in the cell; second, sequencing the products in the cell such that total manpower shortage is minimized. The number of operators needed in a time bucket may exceed the available manpower level since different products have different manpower requirements. In this paper, optimal manpower allocation to stages is accomplished by using a mathematical model. Later, Genetic Algorithm approach is proposed for sequencing products on the cell. Next, a five-phase GA approach is introduced. Finally, several experiments are performed and the results of Classical GA vs. 5-phase GA are compared.

Keywords

Product Sequencing, Genetic Algorithms, Cellular Manufacturing, Synchronization.

1. Introduction

In cellular manufacturing, similar products are grouped together into product families and then manufactured in machine groups called cells. Each cell ideally consists of all of the machines needed to manufacture the family it is assigned. In some industries, self-sufficient cells (completely independent) are not economically feasible. However, in this study we consider the presence of independent cells. Kay and Suresh (1998) summarize the benefits of cellular manufacturing as lower work-in-process (WIP) inventory, lower space requirements, shorter leadtimes, lower total setup times, smaller lot sizes, simpler work flow and simpler production control.

Cellular control issues can be classified as Family Sequencing and Scheduling; Cell Loading; Product Sequencing, Cell Scheduling; Crew Size Determination, and Manpower Allocation to Operations (See Süer, Saiz, Gonzalez (1999), Süer, Cosner, and Patten (2009). This paper deals with product sequencing and manpower allocation decisions in a synchronous cell. Süer and Gonzalez (1993) defined synchronous manufacturing as:

> *"A systematic way that provides a perfect flow of material through the production system by making it available for the right resource at the right time using a periodic approach with the objective of simplifying the scheduling task and minimizing the work-in-process inventory and the flow time"*

Süer and Gonzalez (1993) implemented synchronous manufacturing principles in a jewelry manufacturing plant. The main reason why synchronous manufacturing principles were used was that there were different schedules everyday and implementation of them was heavily dependent on the schedulers and cell supervisors. After the implementation of the uniform time bucket approach, they were able to convert this dynamic and stochastic scheduling problem into a static and deterministic problem which made scheduling much easier to implement. Jobs started and finished at regular and known intervals. By doing this, the need to prepare a different schedule everyday was eliminated. Even though there could be better schedules without implementation of synchronization approach, the likelihood of acceptance and implementation was much higher with synchronization. This approach was later implemented in most manufacturing cells in the company. The objective of this paper is to sequence products in such a synchronized cell environment such that the total manpower shortage is minimized. The literature review is presented in Section 2 and more detailed description of the problem is given is Section 3. Section 4 discusses the proposed solution approaches and experiment results are discussed in Section 5. The paper concludes with brief remarks and future work in Section 6.

2. Literature Review

The problem discussed in this paper was implemented in a jewelry manufacturing company. The cells in this manufacturing environment were labor-intensive. Machines and equipment were inexpensive and light. Therefore, it was possible to move machines around without much difficulty as many of them were mounted on workbenches with wheels. In this plant, there were more operators in a cell than the number of operations. As a result, some of the machines were duplicated to utilize all of the operators and hence maximize production rates. Therefore, the allocation of manpower to different operations was very important. Another critical issue was product sequencing. If product sequencing was not done right, the number of workers needed exceeded the number of workers available in some periods. Obviously, this adversely affected the performance of the cells by either slowing down the production or borrowing operators from other cells, if any available. In some weeks, temporarily workers had to be brought in to deal with manpower shortages.

There were several research work reported in the cellular manufacturing literature in regard to manpower allocation. Süer and Dagli (1994) developed six rules and six algorithms in order to create a knowledge-based system for resource allocation for flexible manufacturing systems. Süer and Dagli (2005) first produced a methodology to minimize total intra-cell manpower transfers. Süer and Tummaluri (2008) discussed learning and forgetting in labor-intensive cells and operator assignments in a multi-period environment. Süer and Alhawari (2012) proposed both Max and Max-Min labor assignment strategies and studied their impact in highly dynamic cellular environments where there may be sudden product mix change. Süer, Arikan, and Babayigit (2008) proposed a fuzzy bi-objective mathematical model which performs several tasks at the same time; deciding number of cells to open, deciding cell sizes, assigning products to cells, determining the sequence of products in each cell. Süer, Arikan, and Babayigit (2009) later studied the effect of different fuzzy operators on the results. Süer, Cosner and Patten (2009) developed various mathematical models for cell loading and product sequencing to minimize makespan, machine requirements and intra-cell manpower transfers. Suer, Kamat, Mese, and Huang (2013) proposed math models for manpower allocation and cell loading to minimize total tardiness in the presence of multiple cells.

There are a couple of works in the literature considering synchronized environment. Burbidge (1975) proposed Period Batch Control (PBC) as a simplified means of controlling manufacturing process. Another approach was implemented in Kumero Oy as reported by Whybark (1984) where products were grouped into five families and manufacturing process was divided into five stages. Süer (1989) suggested Uniform Time Bucket in his work and developed various heuristics and a mathematical model to determine product grouping to be released at each time bucket. In uniform time bucket approach, planning periods are divided into time buckets and manufacturing processes are clustered into stages. The set of jobs move from one stage to the subsequent stage at the end of each time bucket as shown in Table 1. The set of jobs (S_t) needs to be completed in time bucket (t), then they should be processed at stage 4 in period (t-1), at stage 3 in period (t-2), etc. Süer and Gonzalez (1993) proposed 4-hour uniform time bucket approach for cell scheduling in their paper. The principle is based on the “right part”, the “right quantity” and the “right time”. Later, they extended the line balancing concept to the entire manufacturing system again by using uniform time bucket approach as reported in Süer(1998) and in Süer et al. (1999). Riezebos (2003) developed a mathematical model and several heuristics to obtain proper work order release decisions in a synchronous manufacturing cell. Concurrent design of a Period Batch Control (PBC) system by genetic algorithms was proposed by Escobar (2003). The objective was to minimize work-in capital investment, transfer and set-up costs.

Table 1. Uniform Time Bucket Approach

	TIME BUCKETS							
STAGES		t-6	t-5	t-4	t-3	t-2	t-1	t
1		S_{t-2}	S_{t-1}	S_t				
2			S_{t-2}	S_{t-1}	S_t			
3				S_{t-2}	S_{t-1}	S_t		
4					S_{t-2}	S_{t-1}	S_t	
5						S_{t-2}	S_{t-1}	S_t

3. Problem Statement

The synchronous manufacturing approach proposed here was implemented in a jewelry company. The manufacturing processes were grouped into five stages. The length of Time Bucket was established as four hours due to ease of implementation (see Suer (1993) for details). Since there are five working days in a week and a single shift is used, the total number of buckets that can be processed in a week per cell is calculated as 10 (=5*2). A crew size of 20 is used in the example problem. Before determining the optimal product sequence, the number of operators to be allocated to stages had to be determined. A mathematical model was used to perform operator allocation to stages. The objective was to maximize production rate. The next step was to determine the required number of time buckets for each product based on their production rate and demand (In this example it is assumed each product requires one bucket). The final task is to sequence these products such that the total manpower shortage during time buckets is minimized.

In the example considered in this section, there are 20 products considered with their optimal manpower levels for each stage based on a crew size of 20 workers as given in Table 2. For example, the optimal allocation of workers for product 1 is 3, 5, 4, 6 and 2, workers for stages 1, 2, 3, 4 and 5, respectively. These products can be sequenced from 1 to 20 as shown in Table 3. A planning horizon of 24 [=20+ (number of stages-1)] buckets are considered in the weekly planning horizon due to the effect of synchronization.

Table 2. Manpower levels for 20 Products

	Products																			
STAGES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	3	3	5	5	3	3	2	2	3	3	2	2	5	5	4	4	4	4	8	8
2	5	5	3	3	8	8	4	4	6	6	3	3	3	3	4	4	3	3	3	3
3	4	4	4	4	2	2	2	2	6	6	5	5	2	2	4	4	5	5	3	3
4	6	6	4	4	3	3	6	6	3	3	5	5	5	5	4	4	5	5	3	3
5	2	2	4	4	4	4	6	6	2	2	5	5	5	5	4	4	3	3	3	3
Total Manpower	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Table 3. Schedule for the Example Problem

	Week-1										Week-2										Week -3			
	Mon		Tue		Wed		Thu		Friday		Mon		Tue		Wed2		Thu2		Friday2		Mon3		Tue3	
	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm
T(time bucket)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Product Sequence	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
Stage1	3	3	5	5	3	3	2	2	3	3	2	2	5	5	4	4	4	4	8	8	3.9	3.9	3.9	3.9
Stage 2	4	5	5	3	3	8	8	4	4	6	6	3	3	3	3	4	4	3	3	3	3	4.2	4.2	4.2
Stage 3	2	2	4	4	4	4	2	2	2	2	6	6	5	5	2	2	4	4	5	5	3	3	3.7	3.7
Stage 4	3	6	6	6	6	4	4	3	3	6	6	3	3	5	5	5	5	4	4	5	5	3	3	4.4
Stage 5	4	4	6	6	2	2	4	4	4	4	6	6	2	2	5	5	5	5	4	4	3	3	3	3
Remaining Manpower	4	0	-6	-4	2	-1	0	5	4	-1	-6	0	2	0	1	0	-2	0	-4	-5	2.1	2.9	2.2	0.8

A product that enters the cell in time bucket 1 in stage 1 moves to stage 2 in time bucket 2; moves to stage 3 in time bucket 3 and so on. Finally, it leaves the manufacturing cell at the end of time bucket 20. Grey cells that are at the left bottom show the manpower levels based on the scheduling decisions made in the previous period (for example in this case the last four products scheduled in the previous week are Products 9, 10, 11 and 12, respectively). There are also black cells at the right up side of the table. These values are the estimates for the manpower levels for the next four periods, and are calculated as the average of corresponding manpower levels at that stage. For example the estimate for stage 1 is calculated as (3+3+5+5+3+…+4+4+8+8)/20 = 3.9. In some time buckets, available number of operators may not be sufficient. For example in time bucket 4, there is a shortage of 6 operators where number of available operators is 20 and number of operators needed is 26. In this example, there are manpower shortages in 8 buckets, namely, buckets 3, 4, 6, 10,11,17,19 and 20. The objective in this paper is to sequence products such that the total manpower shortage in the planning horizon is minimized. In practice, manpower shortage can be handled either by reducing quantity to be produced for those particular products or by bringing additional workers from other cells or production departments, if they are available. Another option is to bring temporary workers to be used in those planning horizons.

4. The Proposed Solution Approaches

The proposed methodology consists of two main phases: 1) Manpower Allocation Phase, and 2) Product Sequencing Phase. They are discussed in the following sections in detail.

4.1 Manpower Allocation Phase

The first phase is the allocation of manpower to different stages to maximize the production rate. This model is run for each product independently. It is assumed that processing times are known. The model is described below:

Index:

j — *stage index*

Parameters:

t_j — *processing time for stage j*

U_j — *upper limit for the number of workers for stage j*

T — *total number of workers available in the cell*

NS — *number of stages*

Decision Variables:

PR — *production rate*

m_j — *number of workers (manpower level) needed for stage j*

Objective Function:

$$Maximize\ z = PR \tag{1}$$

Subject to:

$$\frac{m_j}{t_j} \geq PR \qquad j = 1, \ldots, NS \tag{2}$$

$$m_j \leq U_j \qquad j = 1, \ldots, NS \tag{3}$$

$$\sum_{j=1}^{NS} m_j \leq T \tag{4}$$

m_j, integer and positive for all j **(5)**

PR, positive

The objective is to maximize the production rate to be obtained from the cell as shown in (Eq. 1). The production rate of an operation should be greater than or equal to the production rate of the cell as enforced by (Eq. 2). The number of workers assigned to an operation should not exceed the upper limit for that operation as indicated in (Eq. 3). This may be necessary due to machine/equipment restrictions for that operation. Finally, the total manpower available should not be exceeded (Eq. 4). Decision variables are defined in (Eq.5).

4.2 Product Sequencing Phase

In this paper, we use Genetic Algorithms (GA) for product sequencing. The chromosome representation illustrated in Figure 1 is used where each job corresponds to a gene and a chromosome shows the entire sequence of products. In this case, the product sequence is established as 10-6-3-7-5-4-8-9-1-2.

10	6	3	7	5	4	8	9	1	2

Figure 1. Chromosome Representation for GA

First, initial population is generated randomly. Reproduction probabilities of chromosomes are calculated next. After chromosomes are selected, mating partners are identified. Mating partners go thru crossover and then mutation operator is applied to each offspring. Having parents and offspring, selection strategy is applied to generate the next population. This process is repeated until the specified number of generations is carried out. .

The reproduction probabilities are assigned based on fitness values (Fitness values are added a value of 1 in order to avoid division by 0). The reproduction probability for each chromosome is computed as given in equation 6. P_c is reproduction probability for chromosome c, r is population size and f_c is fitness function value for chromosome c.

$$p_c = \frac{1/(f_c + 1)}{\sum_{c=1}^{r} 1/(f_c + 1)} \qquad (6)$$

Every new population member has a match in the mating partners population. Mating is performed based on the crossover probability. In this paper, the position-based crossover is used. After the crossover, the population size is doubled (new population + mating partners' population). This newly generated population goes through mutation namely, insertion mutation. The detailed definition of these operators can also be found in Gen et al. (1997). Population size is doubled after crossover. The next generation of chromosomes is selected by using the Roulette Wheel Strategy. This process is repeated until the specified number of generations is reached (stopping criterion).

4.3 Five-Phase GA

In this paper, a five-phase GA approach is used and later experimented with. In this approach, the total number of generations is divided into five phases as discussed below:

Phase 1. Entire Population goes through only crossover.

Phase 2. Population is divided into two segments and the first segment goes through crossover and mutation while the second segment goes through just crossover.

Phase 3. Population is divided into three segments and the first segment goes through just mutation, the second segment goes through crossover and mutation and the last segment goes through just crossover

Phase 4. Population is divided into two segments and the first segment goes through just mutation while the second segment goes through crossover and mutation.

Phase 5. Entire Population goes through just mutation.

This is significantly different than the classical GA approach where chromosomes go through both crossover and mutation. The user can specify % chromosomes of the population for each segment in each phase as well. Another feature presented in this paper is that the user can specify a trigger point (number of generations) for each phase. In the next section, an experiment is also performed for different trigger point values.

5. Experiments and Results

The data set used in this experiment contains 20 jobs and the number of stages is 5. There is only 1 shift and the length of time bucket is 4 hours. We restrict this experiment to two cells. Hence this planning horizon covers a period of 2 weeks.

5.1 Traditional GA vs. Five-Phase Approach

The total number of generations is divided into five phases as shown in Figure 2. In this example, there are 400 generations which are divided into five phases. Every phase runs for 20% of 400 generations which is equal to 80, in other words, trigger point is 80. In the first phase, chromosomes just go through crossover for 80 generations. Then, in the second phase, half of the population goes through crossover and mutation while other half goes through just crossover and so on.

In this section, an experiment is performed considering the following GA parameters:

- 3 mutation Probabilities: 0.1, 0.3 and 0.5
- 3 crossover probabilities: 0.6, 0.8, and 1
- 3 position-based crossover probabilities: 0.1, 0.3 and 0.5.

A total of 270 runs is made (10 runs for each combination). The best result and the average of 10 replications are shown in Table 4 for each position-based crossover probability. Mutation probability of 0.1 and crossover probability of 0.6 worked the best almost for any position-based crossover (PBC) probability. Five-phase GA outperformed Traditional GA in every instant with respect to both the best values and average values. Similarly PBC=0.1 performed better than PBC=0. 3 and PBC=0.5.

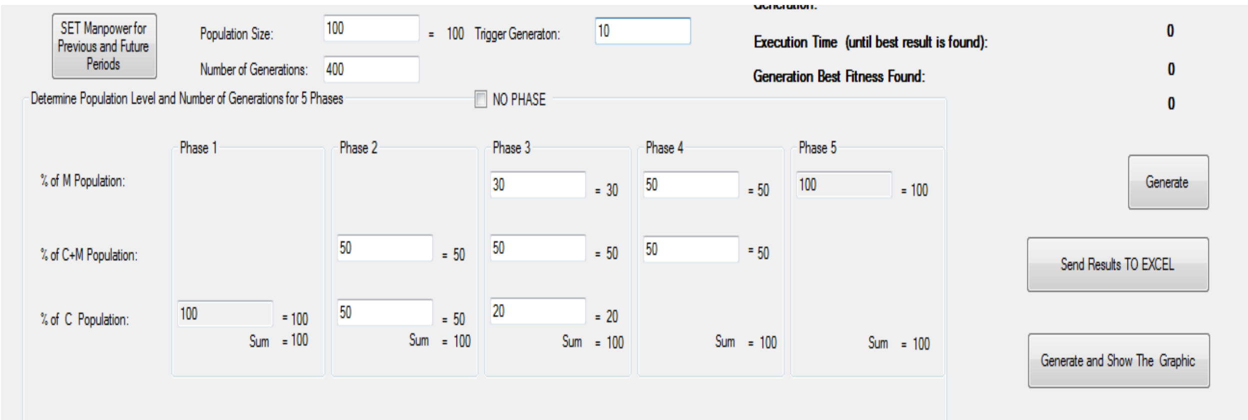

Figure 2. Five-Phase GA Approach

Table 4. Schedule for the Example Problem

	PBC=0.1				PBC=0.3				PBC=0.5			
	TGA		5PGA		TGA		5PGA		TGA		5PGA	
Pm,pc	Best	Av	Best	Av	Best	Av	Best	Av	Best	Av	Best	Av
.1,.6	16	18	14	15	17	19	15	17	17	19	16	17
.1,.8	17	18	14	16	18	19	16	18	18	19	14	17
.1,1	17	19	14	16	18	19	16	17	18	19	16	18
.3,.6	17	20	16	17	18	20	15	18	19	20	14	17
.3,.8	18	20	15	17	18	20	18	19	19	20	17	18
.3,1	18	20	14	16	19	20	16	19	18	20	18	19
.5,.6	19	20	15	17	18	20	15	18	19	21	16	18
.5,.8	19	20	15	17	18	21	17	19	19	21	17	19
.5,1	19	21	14	17	19	21	18	19	20	21	18	19

5.2 *Number of Generations vs. Population Size*

In the second part of the experimentation, population size is compared against the number of generations for the same data set. The objective is to decide whether to use bigger population size or bigger number of generations to reach the best answer. Five different combinations are tested. In the first combination, the population size is kept 100 while the number of generations is 2500. In the second combination, the population size is 250 while the number of generations is 1000 and so on as given in Table 5. The total number of problems solved remains the same in all cases (250000 instances). Ten 10 replication are generated for each option. Crossover, Mutation and Position-Based Crossover parameters are fixed at 0.6, 0.1, 0.1, respectively, based on the results of the experiment performed in the previous section. Obviously, the best solution obtained significantly improved from 14 in the previous section to 11 in this section. In the previous section, the total number of problems solved was 40000 (pop size 100 and #gen 400). We could not observe any dominance except that higher population size produced lower average values.

Table 5. Population size vs. Number of Generations

	Options				
	1	2	3	4	5
Run	ps 100 #g 2500	ps 250 #g 1000	ps500 #g 500	ps 1000 #g 250	ps2500 #g 100
1	13	14	13	15	15
2	14	11	13	13	13
3	12	14	14	14	12
4	13	14	15	12	13
5	14	14	16	13	14
6	13	14	15	15	15
7	15	13	15	13	12
8	13	14	12	12	14
9	14	13	16	13	11
10	13	15	15	14	14
Av	13.4	13.6	14.4	13.4	13.3

5.3 Comparing the different trigger point in 5-phase approach

In this case, 600 runs (12 different trigger point* 50 replication for each) are made using 100 population size and 2500 generations. The crossover, mutation and position-based crossover parameters are fixed at 0.6, 0.1, 0.1 respectively. The results are summarized in Table 6. %gen shows the population size % that corresponds to trigger point. The number of cycles indicates how many cycles of 5-phase is repeated during the entire run of 2500 generations. For example, the 5-phase approach mentioned earlier is applied 50 times for the 1st option. The best, worst and the average value of 50 replications are summarized in the table along with frequency of 11 and the frequency of 12 (the second best know solution). The trigger values that produced the best value 11 are 250, 300, 500 and 700. On the other hand, the best average values were obtained when the number of cycles was higher (except 50). When the number of cycles is less than five, the 5PGA indeed approaches to traditional GA and therefore did not produce very good results. This is consistent with results reported in Section 5.1.

Table 6. Summary of Trigger Point Options

	Trigger Point Options											
	1	2	3	4	5	6	7	8	9	10	11	12
Trigger point	10	50	100	150	200	250	300	500	650	700	1000	1250
%gen	.4	2	4	6	8	10	12	20	26	28	40	50
Cycles	50	10	5	3.3	2.5	2	1.6	1	.77	.71	.5	.4
Phase run ends	P5	P5	P5	P2	P3	P5	P4	P5	P4	P4	P3	P2
Best	12	12	12	12	12	11	11	11	12	11	13	12
worst	17	15	15	15	16	16	17	17	17	18	17	19
frequency of 12	1	3	4	4	3	1	3	0	2	1	0	1
frequency of 11	0	0	0	0	0	1	1	1	0	1	0	0
Average	14.32	13.42	13.58	13.9	13.9	14.1	14	14.52	14.7	14.84	14.4	14.86

6. Concluding Remarks and Future Work

There were several issues observed in the study. One of the key points is that selection of GA parameters affects the results significantly. The selection of the best parameters may not always be straightforward where the best values and average values can lead to different selections. One clear conclusion is that 5PGA always produced better results. This is interesting where crossover and mutation operators are applied in a dynamic fashion. In this study 5PGA concept is further expanded with trigger point concept where this 5-phase is implemented in many cycles. Early experimentation results show that selection of trigger point is important in terms of the best value and the best average. Trigger point helped to reach the best known value 11 compared to the case where it was not used for the corresponding 2500 generations and 100 population size case.

As a future work, we would like to expand this application to multi-cell environment. Another direction is to compare the results with the optimal solution. Finally, we could also experiment with population segment percentages used in each phase.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Alternative Global Supply Chain Design Strategies for A Blood Sugar Strip Manufacturer Considering Layered Cellular Design

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Abstract

This paper discusses alternative supply chain design strategies for a global blood sugar strip manufacturing company. Two main alternatives considered are: 1) Single location manufacturing plant to meet world demand; 2) three manufacturing plants located in three regions to meet world demand. Manufacturing plants are designed considering layered cellular design approach under stochastic demand. This approach allows three types of cells to be formed: 1) dedicated cells for families, 2) shared cells, cells to be shared by two families, 3) remainder cells, cells to be used by three or more families. The main focus of this paper is to compare both alternatives with respect to numbers of manufacturing cells and number of machines needed. This is significant in terms of determining investment requirements for both options. We will also discuss detailed operational control issues in one of the plants and discuss simulation results to validate the results obtained through layered design methodology.

Keywords
Supply Chain Design, Cellular Manufacturing System, Simulation

1. Introduction
This research focuses on designing a manufacturing system for a global blood sugar strip manufacturer. Three manufacturing facilities are assumed to meet the demand of three regions. Using cellular manufacturing concepts, number and type of manufacturing cells are determined for each manufacturing facility considering demand data. Later, this supply chain strategy is compared with the one where all manufacturing is done in a single facility. A probabilistic method is used first to do system design and then the theoretical results are verified using simulation analysis.

1.1 Classification of Manufacturing System
The type of a manufacturing system mostly depends on the layout of the manufacturing system. Manufacturing system is classified into four categories based on the layout which is in Figure 1: process layout, fixed layout, cellular layout and product layout. Fixed Layout deals with heavy products, which stay in the same position and workers, machines and equipment are brought to the product (Süer, Huang & Maddisetty, 2010). Product Layout is used when product volume is high and product variety is low. Product layout is usually very efficient but inflexible system. Process Layout is used for low product volume systems with a high product variety (Süer, Huang & Maddisetty, 2010). These systems are very flexible but not very efficient. Cellular Layout is more flexible than Product Layout. It suits for high product variety with low to moderate demand (Süer, Huang & Maddisetty, 2010). Figure 1 shows the classification of four layout types.

Cellular Manufacturing is based on the grouping of similar products with respect to common processes into one cell. In the real world, many uncertainties exist in the system such as demand uncertainty, supply uncertainty and processing uncertainty. These uncertainties have been discussed in related research. The uncertainties of product demand and processing times are considered (Süer, Huang & Maddisetty, 2010). By probabilistic market demand calculation, the part-family assignment is achieved (Süer, Huang & Maddisetty, 2010). Then, low utilized cells are grouped to increase the utilization of the system.

1.2 Supply Chain
Supply chain is the network connecting between suppliers, manufacturers, distribution centers and customers (New & Payne, 1995). Many supply chain models were discussed (Dicken, 1992). Among them, globally concentrated production model, host market production model and regional/global product specialization model are mentioned. Specifically, each of the geographic regions covers its own demand of that geographic region in the host market production model as shown in Figure 2. On the other hand, one manufacturing facility produces all the demand from all over the world in the globally concentrated production model as shown in Figure 3. In this study, these two models are discussed.

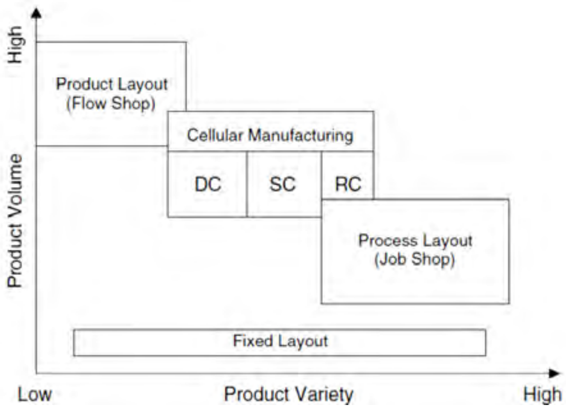
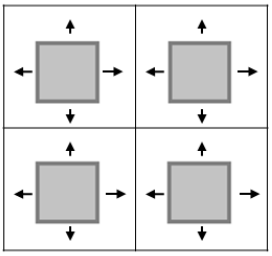


Figure 1: Four Types of Manufacturing Layout (Süer, Huang & Maddisetty, 2010)



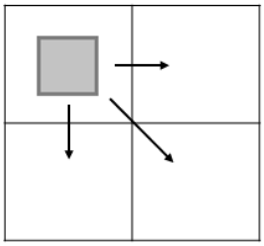


Figure 2: Host Market Production Model (Dicken, 1992)

Figure 3: Globally Concentrated Production Model

2. Literature Review

Literature regarding to global supply chain and manufacturing systems is summarized in this section.

2.1 Global Location Strategy Models

Supply chain model includes three logistical drivers and three cross functional drivers (Chopra & Meindl, 2004). Three logical drivers are facilities, inventory and transportation and three cross functional drivers are information, sourcing and pricing. Many factors affected a sophisticated network of multinational manufacturing facilities (Brush, Maritan & Karnani, 1999). This integrated network included independent and integrated plant choices. Besides considering facility selection, a facility location model was developed to study the location decision of high technology firms (Haug, 1992). The model identified the international manufacturing facility location based on domestic and potential international production markets, which allowed production to be transferred from domestic manufacturing facilities to foreign ones. A two-phase multi-screening approach including production capacity was developed for incorporating uncertainty about exchange rates and exchange rate risk in an international production and sourcing model (Lowe, Wendell and Hu, 2002). National market was improved into the global supply chain market by considering connection among global markets (Canel & Das, 2002). In order to solve the global manufacturing problems, an integrative mathematical model was developed to connect global manufacturing and marketing (Canel & Das, 2002).

2.2 Cellular Manufacturing Design / Group Technology

Group Technology (GT) was introduced to improve productivity in the Cellular Manufacturing System (CMS). Group Technology was introduced into cellular manufacturing (Hyer & Wemmerlov, 1982). Not many works in the literature were used with fuzzy concepts to deal with multi-objective framework in the process planning (Singh & Mohanty, 1991). A supplementary procedure was proposed to solve the limitation of Adaptive Resonance Theory (ART) (Chen and Cheng, 1995). They mentioned that the performance of ART depended on the initial matrix of bottleneck process. Moreover, a new mathematical model based on cell utilization was conducted (Mahdavi, Javadi, Fallah-Alipour & Slomp, 2007). A mixed integer non-linear model was analyzed for CMS (Bulgak & Bektas, 2009). In their paper, the proposed model was an integrated approach to combine production planning and system reconfiguration. This CMS model was a new model, which includes sequence, duplicate machines, capacity of machines and lot splitting.

The literature reviews discussed so far included the deterministic CMS problem. However, cellular manufacturing is difficult to design in the real world due to uncertainty of the manufacturing process. In order to deal with the uncertainty of product demand along with processing time, another research is proposed (Süer, Huang and Maddisetty, 2010). A heuristic methodology was conducted to distinguish cell types in the CMS - Dedicated Cell (DC), Shared Cell (SC) and Remainder Cell (RC). The product family configuration and cell allocation are accomplished by mathematical analysis. The designed manufacturing system turned to successfully solve the uncertainty of product demand and processing time through simulation method. The methodology is implemented in the current research for the purpose of designing the manufacturing system given the market demand, part-family formations, and the operations required to process the products.

3. Problem Definition

In this research, a blood glucose test strip manufacturing system is considered to study the alternative supply chain design approaches, namely independent facilities per region vs. single manufacturing facility. The procedure used to decide shared manufacturing cells is explained in Section 3.1. Subsequently, comparison between independent and single manufacturing design is conducted in Section 3.2. Customers from three regions are considered to be the most influential consumer force – Europe, Asia and North America. Three manufacturing facilities are assumed to produce the products – Ireland, China and Puerto Rico. The production data and manufacturing processes are gathered from Lobo (2006). Most of the demand data are converted into common units by considering market share, revenue, and product price from Ateş (2013).

3.1 Manufacturing Cell Design

In most manufacturing systems, different products require to be processed on different machines. Due to high product variety, products are grouped into several families based on their similarity. Table 1 shows an example of product-machine incidence matrix. In this table, “1” in row i and column j indicates that product i needs to be produced on machine j. For example, Product 1 (P1) is processed on Machine 1 (M1), Machine 2 (M2) and Machine 3 (M3). One can observe that products with similar manufacturing processes are grouped together. Table 2 shows families and cells they are assigned to in cellular manufacturing.

Table 1: An Example of Product-Machine Incidence Matrix

	M1	M2	M3	M4	M5
P1	1	1	1		
P2	1		1		
P3		1	1		
P4				1	1
P5				1	1
P6	1		1		1
P7	1				1

Table 2: Product Families and Cells

Family	Products	Cell	Machines in the Cell
F1	P1, P2, P3	Cell1	M1, M2, M3
F2	P4,P5	Cell2	M4, M5
F3	P6,P7	Cell3	M1, M3, M5

However, in real life manufacturing systems, some product families may have quite high demand, which means they cannot be produced in one cell. Table 3 shows this multiple cell production system. For example, due to high demand, product families 1, 2 and 3 may need 2, 3 and 2 cells, respectively.

Yet another possibility is that demand values for product families follow a probabilistic distribution. In some cases, expected utilization for some cells of families may be low. As a result, several product families may be expected to share one cell. A Dedicated Cell (DC) deals with one product family. A Shared Cell (SC) operates two product families, which have relatively similar operations. A Remainder Cell (RC) handles more than two product families. Both Shared Cells and Remainder Cells usually handle product families that have medium or low expected utilization values for some of its cells. Table 4 shows the cell sharing between three product families. For example, Cell 1 (C1) is Dedicated Cell for Product Family 1(F1). C2 is also Dedicated Cell for F2. C3 is a Remainder Cell to be shared by F1, F2 and F3. Finally, C4 is a Shared Cell between F2 and F3.

Table 3: Family vs. Multiple Cells due to High Demand

	C1	C2	C3	C4	C5	C6	C7
F1	1	1					
F2			1	1	1		
F3						1	1

Table 4: Layered Cellular Design due to Stochastic Demand

	C1	C2	C3	C4
F1	1		1	
F2		1	1	1
F3			1	1
	(DC)	(DC)	(RC)	(SC)

3.2 Alternative Supply Chain Designs

In this section, two alternative supply chain design strategies are discussed. Strategy 1 discusses the independent supply chain design which means the manufacturing facilities produce products independently in each region, namely North America, Asia and Europe by using three manufacturing facilities located in Puerto Rico, China and Ireland, respectively. Strategy 2 is the single location manufacturing system in which all of the products are produced in one location.

3.2.1 Strategy 1: Independent Supply Chain Design

In this strategy, each region produces many types of products to meet the demand of its own demand. Products are produced independently in different facilities, which lead to no transportation and information sharing between different regions. Figure 4 shows that the blood sugar strips are produced in three manufacturing facilities – China, Ireland and Puerto Rico.

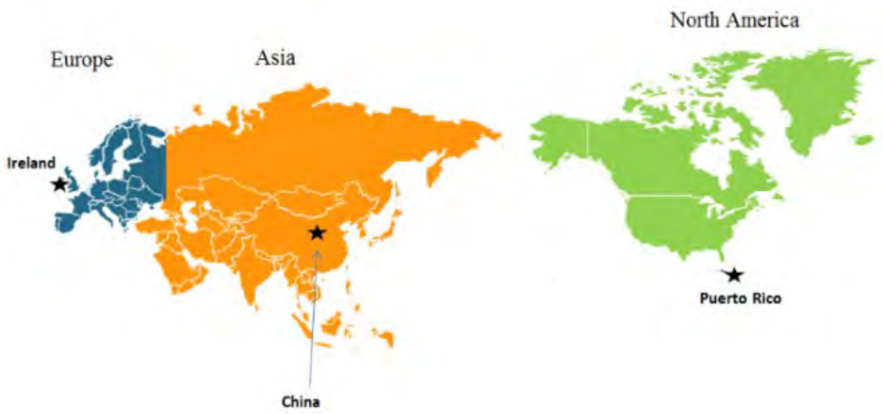


Figure 4: Independent Manufacturing Systems

3.2.2 Strategy 2: Single Manufacturing Facility Design

In this strategy, one single manufacturing facility produces all the products. The location analysis of this facility is not within the scope of this paper.

4. Methodology Used

In each manufacturing facility, there are both fabrication and packaging cells. Products are divided into five product families based on product family similarity in manufacturing processes. In this study, we assume that product families have been already identified.

Two alternative models will be discussed in Section 4.1 and Section 4.2. An independent supply chain model is presented in Section 4.1. Cell utilizations are calculated by using cell capacity, product demand, etc. (Section 4.1.3). Each cell capacity is assumed 2000 hours annually. Cell utilization captures the usage of each cell. By considering the cell utilization, different cells can be combined into one as long as capacity is available (Section

4.1.4). Single manufacturing model is discussed in Section 4.2. Then simulation is implemented to realize the model together with the optimal result of the research (Section 4.3). In Figure 5, the general methodology is presented.

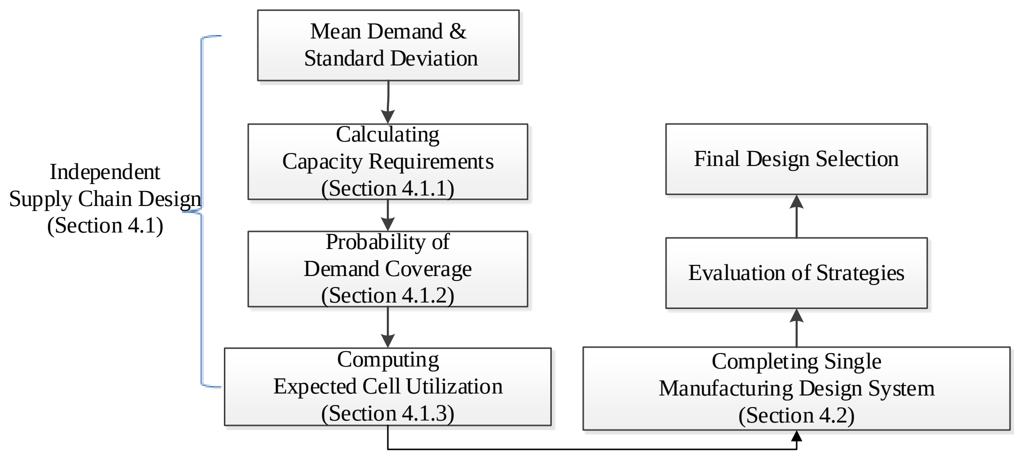


Figure 5: Methodology Flowchart

4.1 Independent Manufacturing Facilities

4.1.1 Mean Capacity Requirements and Standard Deviation

Historical demand values of four companies – Roche, LifeScan, Bayer and Abbott from 2002 to 2010 are used to calculate the 2011 demand in the research by Ateş (2013). In this research, it is assumed that demand is normally distributed. Standard Deviation (σ) values for each product family are generated as a percentage of the mean demand (20% - 25%). It is assumed that if Mean Demand is high, low percentage will be assigned to minimize the uncertainty among data. Most of the mean demands by family in all markets are from (2013), which is shown in Table 5. Also, Standard Deviations (σ) in three regions are given in Table 5.

Table 5: Mean Demand and Standard Deviation by Family in Three Regions

	China			**Ireland**			**PR**		
Family	Mean	%	STDEV	Mean	%	STDEV	Mean	%	STDEV
1	1,422,286	25	355,571	1,422,925	25	355,731	1,337,087	25	334,271
2	7,098,188	24	1,703,565	7,101,377	24	1,704,330	6,672,986	24	1,601,516
3	6,711,423	24	1,610,741	6,714,438	24	1,611,465	6,309,389	24	1,514,253
4	24,313,261	21	5,105,784	22,000,00	21	4,620,000	22,856,826	21	4,799,933
5	3,137,454	25	784,363	3,138,863	25	784,715	2,949,511	25	737,377

Having mean demand values and standard deviations, the mean capacity requirements by product family are calculated by using Equation 1 in Maddisetty (2005). Bottleneck Processing Time is defined by the bottleneck machine as the longest processing time in the cell.

$$MCR_{FamilyNo} = Mean_{Demand} * \frac{BottleneckProcessingTime}{60} \ (hr) \qquad (1)$$

For example, Mean Capacity Requirements for Product Family 1 in the manufacturing system of China region is decided by Mean Demand by Product Family 1 in China region which is 1,422,286. BPT (Bottleneck Processing Time) is 1/80 = 0.0125 min in the China region. The results of Mean Capacity Requirements and standard deviation for different regions are shown in Table 6.

$$MCR_{F1} = 1{,}422{,}286 * \frac{0.0125}{60} = 296$$

$$StandardDeviation_{Capacity_{F1}} = \sqrt{355{,}571^2 * \frac{0.0125^2}{3600}} = 74$$

Table 6: Mean Capacity Requirements and Standard Deviation for Three Regions

	China		Ireland		PR	
Family	**MCR**	**STDEV**	**MCR**	**STDEV**	**MCR**	**STDEV**
1	296	74	296	74	279	70
2	1479	355	1479	355	1390	334
3	1868	448	1869	449	1756	421
4	5065	1064	4583	963	4762	1000
5	654	163	654	163	614	154

4.1.2 Demand Coverage Probabilities

The demand coverage probability shows the probability that a given number of cells will meet the demand. In this paper, the number of cells to process the particular family of products is unknown. At the same time, demand is assumed to follow the normal distribution. The annual labor time in one cell is 2000 hrs. Mean Capacity Requirement (MCR) is calculated in Section 4.1.1. Demand Coverage Probability (DCP) for a family and cell combination is calculated by Equation 2 in Maddisetty (2005).

$$\mathrm{DCP}_{FamilyCell} = Normsdist\left(\frac{2000 * CellNo. - MCR_{FamilyNo}}{STDEV_{Capacity}}\right) \tag{2}$$

For Cell 1 of Product Family 1 for China market, Demand Coverage Probability for a given number of cells is decided by Mean Capacity Requirement and Standard Deviation. Mean Capacity Requirement for Product Family 1 for China region is 296 which is shown in Table 6. Standard Deviation for Product Family 1 for China region is 74, which is also shown in Table 6. Based on these values, the Demand Coverage Probability for the first cell is 99.99%. In other words, only one cell is sufficient to cover demand almost fully for Family 1.

$$DCP_{F1C1} = Normsdist\left(\frac{2000 * 1 - 296}{74}\right) = 1$$

All the results of Demand Coverage Probabilities for different regions are shown in Table 7. For family 2 in China facility, one cell will cover demand 93% of the time. By adding a second cell, the Demand Coverage Probability jumps to 99.99%.

Table 7: Demand Coverage Probabilities

	China					Ireland					PR				
Cell / Famil	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1	1.00					1.00					1.00				
2	0.93	1.0				0.93	1.0				0.97	1.0			
3	0.62	1.0				0.61	1.0				0.72	1.0			
4	0.00	0.1	0.8	0.9	1.0	0.00	0.3	0.9	0.9	1.0	0.00	0.2	0.8	0.9	1.0
5	1.00					1.00					1.00				

4.1.3 Expected Cell Utilizations

Expected Cell Utilization is determined by using Demand Coverage Probability, Mean and Standard Deviation from Equation 3 to Equation 6 by Süer & Ortega (1998).

$$E(C = X) = P(CR > X) * PU_1 + P(X - 1 \leq CR \leq X) * PU_2 + P(CR < X - 1) * PU_3 \tag{3}$$

Where

E(C=X)	Expected cell utilization for Xth cell in a product family
P (CR>X)	Probability that the Cell Required (CR) number > X
PU_1	Percentage utilization of Xth cell when CR > X, PU1 =1.0
P (X-1≤CR≤X)	Probability that CR between X-1 and X
PU_2	Percentage utilization of Xth cell when CR between X-1 and X
P(CR<X-1)	Probability that CR < X-1
PU_3	Percentage utilization of Xth cell when CR < X-1, PU3 = 0.0

PU_2 is solved by Equation 4.

$$PU_2 = \int_{2000(X-1)}^{2000X} \frac{y * f(y)}{2000 * A} dy - (X-1) \tag{4}$$

Where

y	Variable represents CR
f(y)	Probability density formation for CR
A	Probability that CR between X-1 and X

f(y) and A are calculated by Equation 5 and Equation 6.

$$f(y) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(y-\mu)^2 \frac{1}{2\sigma^2}} \tag{5}$$

$$A = P(X-1 \le CR \le X) \tag{6}$$

For example, Expected Cell Utilization of Product Family 1 for China region is decided by Probability that the Cell Required number larger than 1, Percentage utilization of the 1st cell when CR > 1, Probability that CR between 0 and 1 and Percentage utilization of 1st cell when CR between 0 and 1.

$$E(C=1) = P(CR > 2000) * PU_1 + P(0 \le CR \le 2000) * PU_2 + P(CR < 0) * PU_3 = 0 * 1 + 1 * PU_2 = PU_2$$
$$= \int_0^{2000} \frac{y}{2000 * 1} * \frac{1}{74 * \sqrt{2\pi}} e^{-(y-296)^2 * \frac{1}{2*74^2}} dy = 0.1480$$

All of the results of Expected Cell Utilizations for different regions are shown in Table 8.

Table 8: Expected Cell Utilizations

	China					Ireland					PR				
Family \ Cell	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1	0.15	0.00				0.15	0.00				0.14	0.00			
2	0.73	0.01	0.00			0.73	0.01	0.00			0.69	0.00			
3	0.87	0.06	0.00			0.87	0.06	0.00			0.84	0.04	0.00		
4	1.00	0.96	0.52	0.06	0.00	1.00	0.92	0.36	0.02	0.00	1.00	0.94	0.42	0.03	0.00
5	0.33	0.00				0.33	0.00				0.31	0.00			

4.1.4 Heuristic Algorithm for Layered Cellular Design

Having determined Expected Cell Utilization values, Dedicated Cells (DC), Shared Cells (SC), and Remainder Cells (RC) are identified. The heuristic algorithm is used for identifying cell types (Süer, Huang and Maddisetty, 2010). When all the Expected Cell Utilizations in the three regions are calculated in Section 4.1.3, manufacturing cell types is determined by a heuristic algorithm. Expected Cell Utilizations are sorted in decreasing order with the highest Expected Cell Utilization considered. If the Expected Cell Utilization is 100%, this cell is considered to be a Dedicated Cell (DC). If the Expected Cell Utilization is larger than 50%, a cell will be allocated to a product family. Then other similar product families are allocated to the cell to make the cell coverage close to 100% by considering similarities among families. These cells are named Shared Cells (SC) if they process only two product families. If the Expected Cell Utilization is smaller than 50% and cannot be merged with existing cells, these cells will be grouped together to form a Remainder Cell (RC). Typically, Remainder Cells will process three or more product families.

Table 9: Similarity Coefficients between Product Families

Family	1	2	3	4	5
1		1.00	0.89	0.78	0.70
2	1.00		0.89	0.78	0.70
3	0.89	0.89		0.70	0.80
4	0.78	0.78	0.70		0.89
5	0.70	0.70	0.80	0.89	

The threshold value is the lowest acceptable similarity coefficient that allows two families to be grouped in a cell. The Similarity Threshold is set to 77% in this research. For example, when sorting the ECU for China region, the highest ECU is 100% of Product Family 4 in Cell 1. Then Product family 4 is allocated to Cell 1. When the second cell with 0.96% utilization considered, it is allocated to a new cell – Cell 2. Table 9 is used to search the other similar Product Families with Product Family 4. From Table 9, Families 1, 2 and 5 are considered to share a cell with Product Family 4. Since merging this cell with Family 1 and Family 5 will exceed 100% utilization, the only option is to merge Cell 2 (1% utilization) of Family 2 with Family 4. In China case, there are two Dedicated Cells, two Shared Cells and one Remainder Cell. Similar distributions occur in all cases.

Table 10: Cell Type for Independent Regions

	China					**Ireland**					**PR**				
Family \ Cell	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1				0.15					0.15					0.14	
2		0.01		0.73			0.01		0.73					0.69	
3			0.87	0.06				0.87	0.06				0.84	0.04	
4	1.00	0.96		0.06	0.52	1.00	0.92		0.02	0.36	1.00	0.94		0.03	0.42
5					0.33					0.33					0.31
	DC	SC	DC	RC	SC	DC	SC	DC	RC	SC	DC	DC	DC	RC	SC

4.2 Single Manufacturing Facility

In this section, all the processes are similar to Section 4.1. Total mean demand values are presented in Table 11. Standard deviation values are calculated based on standard deviation values from different regions. Table 12 shows Cell Type for single manufacturing design after heuristic algorithm.

Table 11: Mean Demand and Standard Deviation for Single System

Family	$\textbf{Mean}_{\textbf{Demand}}$	$\textbf{STDEV}_{\textbf{Demand}}$
1	4,182,298	603,914
2	20,872,551	2,893,394
3	19,735,250	2,735,739
4	69,170,087	8,393,616
5	9,225,828	1,332,189

Table 12: Cell Type for Single Manufacturing Design

Family \ Cell	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1														0.44
2						1.00				0.95			0.23	
3					1.00			1.00			0.06		0.69	
4	1.00	1.00	1.00	1.00			1.00		0.97	0.01		0.78	0.08	0.37
5											0.92	0.04		
	DC	DC	DC	DC	DC	DC	DC	DC	DC	SC	SC	SC	RC	SC

4.3 Simulation Experiment

Simulation models can be developed for manufacturing systems in each region. In this section, a simulation model for China region is developed to compare the results with the Expected Cell Utilization in Section 4.1.3. The total running time is assumed to be 2000 hours in a year. Before assigning vials into cells, the vials are held until they are grouped into three units. Lot sizing is important when considering setup time. After decision modules, vials are assigned to different cells. In each cell, vials have several operations processed in different machines. The number of machines and processing times on each machine are included based on different vial types. During the simulation, queue sizes that control the utilization of different cells are identified to reach theoretical cell utilization values as shown in Table 13 and illustrated in Figure 6 for Family 4.

Table 13: Queue Size in China Region

	Cell Utilizations					**Queue Size**				
Family \ Cell	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1				0.15						
2		0.01		0.73					1000	
3			0.87	0.06				100		
4	1.00	0.96		0.06	0.52	100	100			100
5					0.33					

Cell utilization is also an important index in the manufacturing system. Table 14 shows the comparison of average cell utilizations in the simulation model and expected cell utilizations in Section 4.1.3. The maximum deviation is around 4.6%, which indicates that the simulation model realizes therefore results reasonably well.

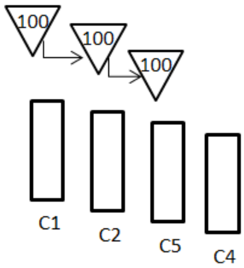


Figure 6: Queue Size Arrangement in Family 4

Table 14: Simulation Cell Utilization vs. Expected Cell Utilization in China Region

Cell	Simulation	Expected Cell Utilization	Deviation (%)
Cell1	0.9985	0.9997	0.1
Cell2	0.9373	0.9611	2.5
Cell3	0.9138	0.8737	4.6
Cell4	0.9607	0.9971	3.7
Cell5	0.8505	0.8489	0.2

5. Conclusion

The comparison between the two designs is presented in Table 14. It shows a single manufacturing facility can produce product families more efficiently, which means cells have higher utilization in single manufacturing system compared to multiple independent plants. However, transportation fees are not included in the analysis, which has an important influence in the final decision. It is then a tradeoff between investment costs versus transportation costs.

Table 14: Comparison between Independent model and Single Manufacturing System

	Independent	Single
# of DCs	7	9
# of SCs	5	4
# of RCs	3	1
# of total cells	15	14
# of Cell Util over 90%	9	12

6. Future Work

Transportation costs will be incorporated into the analysis. Based on this, cost comparisons can be made between these two approaches. So far, setup time has been ignored. Setup time exists in most real world manufacturing systems. The total productive capacity will decrease when setup times exist. The results with setup time will be compared with the original results to evaluate its impact.

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Solving Container Sequencing Problem Using Hybrid Tabu Search Method

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Container terminals are gates of countries open the world. Effective management of terminal operations is important by economic and environmental factors. Total annual handled container number (TEU) is a performance measurement of container terminals. One of the main equipment that is quite expensive purchasing and has high operating costs is quay crane in terminals. Thus, the effective usage of quay cranes is significant. Minimization of empty movements of quay cranes between ship and berth is an objective of quayside operations, so rate of double-cycle moves should be high. Identifying the sequence of containers to be handled as shown on stowage plan that is sent before vessel arrives is investigated as the container sequencing problem in literature. In this paper, hybrid Tabu search method is proposed to handle the reshuffle containers on the vessel and to increase double-cycle ratio of movements. For initial solution of Tabu, Greedy Randomized Adaptive Search Procedure (GRASP) is used. Detailed numerical experiments are conducted to evaluate the performance of the proposed method using well-known benchmark instances. The numerical results indicate that the proposed method provides superior solutions for the benchmark problems compared to those reported in the literature.

Acknowledgements

This work was completely supported by The Scientific and Technology Research Council of Turkey (TUBITAK) under the project number 111M527.

Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

A new methodology for solving real time quay crane scheduling problem

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With the effect of globalization, it is important to deliver the goods to offshore markets in world trade. Marine lines are widely used for transportation of these goods and the volume of trade in container terminals is increasing day by day. There are many papers about container terminal operations, especially scheduling of quay cranes in last decade. All papers about quay crane scheduling problem (QCSP) assumed that processing times of tasks are given. In this paper, processing time of each bay is calculated from the sequence of containers to be handled in the bay by hybrid tabu search algorithm (HTSA). After the processing times of bays is computed, quay cranes are scheduled by genetic algorithm (GA). Reshuffle containers are positioned on the vessel as buffer and it is aimed to increase double-cycle rate because of minimization of empty movements with HTSA. For the first time in the literature, this paper has realistic assumptions that tasks are considered as container; processing times computed by position of each container and quay crane speed. Detailed numerical experiments are conducted to evaluate the performance of the proposed method.

Acknowledgements

This work was completely supported by The Scientific and Technology Research Council of Turkey (TUBITAK) under the project number 111M527.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Various scenario analyses for yard crane scheduling problem

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Links of container shipping which have the most freight transport capacity among the other transportation types are formed by container terminals. Efficiency is the essential item of the competition between them. Terminal efficiency is developed by the effective usage of the cranes in berths and storage area, and of transporters between these areas. In this paper, we focus on yard crane scheduling problem in a non-automated container terminal. For this purpose, same tire based departure time classification rule for an import block, and hybrid assignment and sequencing heuristic for an export block are evaluated. In order to test the methodologies, various scenario analyses with different sizes are designed and the results obtained from these tests are analyzed statistically. By the help of these methodologies, the position of each container in the block is determined and reshuffle operation rates are decreased.

Acknowledgements
This work was completely supported by The Scientific and Technology Research Council of Turkey (TUBITAK) under the project number 111M527.

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Simulations of Linear and Nonlinear Respiratory Mechanics on Optimization of the Human Respiratory Control

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Abstract

In this study, the optimization of the chemical-mechanical respiratory control was simulated to include nonlinear respiratory mechanics. To evaluate the optimality of the system, a quadratic rising neuromuscular drive was applied to a neuro-mechanical effector and the respiratory signals were optimized CO_2 inhalation and exercise input. The model behavior was examined and comparisons were performed under respiratory mechanical loadings, including inspiratory, expiratory, and continuous resistive loading, and normal load. The optimized respiratory signals, including neuromuscular driving pressure, airflow, and lung volume profiles, were compared to evaluate the effects of nonlinear and linear respiratory mechanics.

Keywords

Optimization, respiratory control, nonlinear respiratory mechanics.

1. Introduction

In earlier studies, it was assumed that the mechanical cost of breathing is an explicit function of the respiratory neural driving pressure (Poon et al., 1992; Lin et al., 2012) and is parameterized by the mechanical constraints of the respiratory system. A quantitative description of the mechanical effector that relates the neural respiratory output to mechanical airflow is essential to optimize the neural input to the respiratory muscles. Such an effector was described earlier by the electrical R-C model based on a lumped-parameter model (Younes & Riddle, 1981a,b) to relate respiratory neural and mechanical outputs. On the other hand, the linear parameters R_{rs} and E_{rs} (Poon, 1987; Poon et al., 1987) were used to represent the total flow-resistive and volume-elastic components, respectively, which included the passive resistance and elastance of the lung, chest wall, and airways.

A mathematical model was firstly derived (Golden et al, 1973) to describe the pressure-flow relationship in the ventilatory system under conditions of a constant lung volume. It was observed that during inspiration, flow was determined mainly by the overall airway resistance, but that during expiration, airway collapse limited flow to a value that was determined by small airway resistance and lung elastic recoil. The cumulative total resistance of the respiratory system is known to be approximately 3 cm-$H_2O \cdot l^{-1} \cdot s$. Meanwhile, the resistance seems greater during expiration than inspiration and the majority of the resistance being offered by the upper airways (England et al., 1982; Gautier et al., 1978). Past experimental results (Stanescu et al., 1978; Hyatt & Wilcox, 1961) also demonstrated that substantial expiratory glottal resistance is lost progressively during graded exercise in response to increased airflow rates during hyperventilation and exercise hyperpnea. Poles et al. (1991) modeled a part of the nonlinear respiratory mechanics by partitioning the total system into lung and chest-wall mechanics during constant-flow inflation in mechanically ventilated patients. Meanwhile, Liu et al. (1998) also demonstrated it by integrating airway/lung mechanics, pulmonary blood flow, and gas exchange for a normal human subject executing the forced vital capacity maneuver.

In this study, the earlier model of optimal respiratory control was extended to replace the linear R-C model (Poon et al., 1992; Lin et al., 2012) with a nonlinear respiratory mechanics (Hirayama et al. 1995). However, instead of using a sinusoidal inspiratory-airflow waveform, an instantaneous neuromuscular drive was employed for optimization. The spontaneous airflow and lung-volume profiles are optimized through a neural-mechanical effector with the nonlinear respiratory mechanics. Simulations were performed under eucapnia and hypercapnia to study the effect of the respiratory mechanics on respiratory signals and breathing patterns.

2. The Control Model

Figure 1 illustrates the model of optimal chemical-mechanical respiratory control and the simulation prospect of this study. A simulation strategy has been implemented successfully based on a mathematical model of optimal respiratory control (Poon, 1987; Poon et al., 1992). The model behavior has also been simulated with a linear respiratory mechanics under CO_2 inhalation and muscular exercise by using MATLAB and LabVIEW (Lin et al., 2012; Lin et al., 2014).

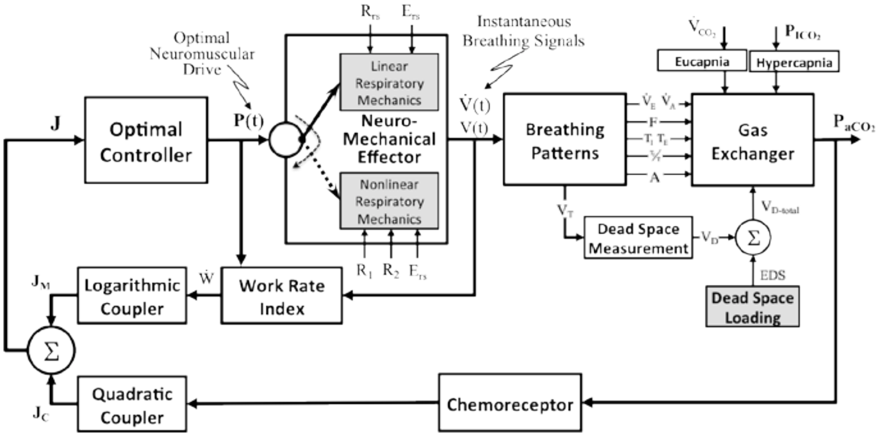


Figure 1: The optimal chemical-mechanical respiratory control with linear and nonlinear respiratory mechanics.

2.2 Neuromuscular Drive

The neuro-mechanical effector relates the neural respiratory output to the resultant mechanical airflow and is required for optimizing the neural input to the respiratory muscles to optimize the ventilatory airflow ($\dot{V}(t)$, L/min). The effector can be described by the electrical analog of modeled respiratory mechanics that describes the resistances and elastance of the lung, chest wall, and airways. The neuromuscular driving pressure (P(t), cm-H_2O) is modeled as inspiratory and expiratory phases; the inspiratory pressure is approximated by a quadratic function and the expiratory pressure is represented by an exponential discharge function:

$$P(t) = a_0 + a_1 t + a_2 t^2 \qquad 0 \le t \le t_1 \tag{1}$$

$$P(t) = P(t_1)\cdot e^{-\frac{t-t_1}{\tau}} \qquad t_1 \le t \le t_1 + t_2 \tag{2}$$

where the parameters a_0 and a_1 in Eq. (1) represent, respectively, the net driving pressure and the rate of increase of this pressure at the onset of the neural inspiratory phase, and the parameter a_2 describes the shape of the wave, and t_1 (s) and t_2 (s) represent the neural inspiratory and expiratory durations, respectively. In Eq. (2), $P(t_1)$ is the peak inspiratory pressure (in cm-H_2O) at the end of inspiration (t_1), and τ denotes the rate of decline of inspiratory activity. We previously successfully simulated the optimized neuromuscular drive with linear breathing mechanics of an R-C model under eucapnic and hypercapnic conditions at various levels of exercise CO_2 output ($\dot{V}_{CO_2}$ = 0.2~1.0 L/min) and inhaled CO_2 (P_{ICO_2} = 1%~7%).

2.3 Gas Exchanger

The gas exchanger depicts the pulmonary exchange events subject to the control signal $\dot{V}_E$ (total ventilation, L/min) and the disturbances in inhaled and metabolic CO_2 (P_{ICO_2}, Torr, $\dot{V}_{CO_2}$, L/min). The system output is the arterial CO_2 pressure (P_{aCO_2}, Torr). The gas exchanger equation describes the dependence of P_{aCO_2} on total ventilation and other disturbances:

$$P_{aCO_2} = P_{ICO_2} + \frac{863 \cdot \dot{V}_{CO_2}}{\dot{V}_A} = P_{ICO_2} + \frac{863 \cdot \dot{V}_{CO_2}}{\dot{V}_E\left(1 - \frac{V_D}{V_T}\right)} \tag{3}$$

where P_{aCO_2} is assumed to be identical to the mean alveolar P_{CO_2}. Equation (4) describes the steady-state effect of ventilation on P_{aCO_2} subject to any disturbances in inhaled and metabolically produced CO_2. To account for the changes in anatomical dead space with an airway caliber, the empirical relation of Eq. (4) is employed:

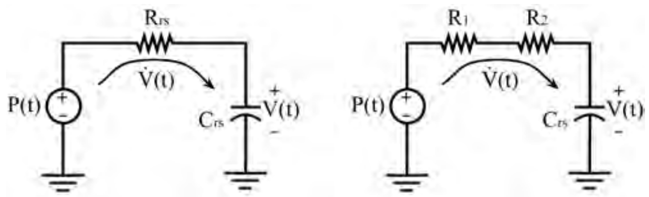
$$V_D = 0.037 \cdot VC \cdot \left(1 + \frac{V_T}{n}\right) \tag{4}$$

where VC is the vital capacity (L), V_T is the tidal volume (L), and EDS is the imposed external dead space (L). Previously, we used a linear model of breathing mechanics to study the effect of added dead space on optimal respiratory signals and breathing patterns under mechanical loadings and CO_2 breathing. However, in this study, our aim was to compare the use of linear and nonlinear respiratory mechanics on the model behavior of the optimal respiratory control with the external dead space set to be nil. Based on the optimized pressure profiles of Eqs. (1) and (2), for any given respiratory resistance and elastance, we can obtain the breathing patterns, including tidal volume (V_T, L), breathing frequency (f, bpm), total ventilation ($\dot{V}_E$, L/min), and alveolar ventilation ($\dot{V}_A$, L/min).

3. The Models of Respiratory Mechanics

3.1 Neuro-mechanical Effector

Instantaneous airflow is controlled physiologically by neural impulses from the respiratory center (controller). The neuro-mechanical effector, which relates the neural respiratory output to the resultant mechanical airflow, is required for optimizing the neural input to the respiratory muscles to optimize the ventilatory airflow ($\dot{V}(t)$, L/min). The mechanical work of respiration results from the frictional resistance to airflow in the airways and the stretching of the elastic walls of the lungs and thorax. The neuro-mechanical effector can be described by the electrical analog of the linear or nonlinear model of respiratory mechanics, which characterizes the resistance of the airways, the lung inertance, and the compliance of the alveoli. To simplify the mechanical model of the respiratory system, the inertance was neglected when switching from the R-L-C model to the R-C model.



(a) (b)

Figure 2: The electric RC model of the Neuro-mechanical effector: (a) linear respiratory mechanics model; (b) nonlinear respiratory mechanics model.

3.2 Linear Respiratory Mechanics

In previous studies (Poon et al., 1992; Lin et al., 2012; Lin et al., 2013; Lin et al., 2014), we described the neuro-mechanical effector by using the electrical R-C model (Fig. 2(a)) based on a lumped-parameter model (Younes & Riddle, 1987a, b) for relating respiratory neural and mechanical outputs. In this model, the equation of motion is given by the following dynamic equation:

$$P(t) = \dot{V}(t) \cdot R_{rs} + V(t) \cdot E_{rs} \tag{5}$$

The parameters R_{rs} (cm-$H_2O \cdot L^{-1} \cdot s$) and E_{rs} (= $1/C_{rs}$, cm-$H_2O \cdot L^{-1}$) in Eq. (5) represent the total flow-resistive and volume-elastic components, respectively, which include the passive resistances and elastance of the lung, chest wall, and airways. Thus, the nonlinear pressure-flow and pressure-volume characteristics are linearized around the relaxation pressure.

3.3 Nonlinear Respiratory Mechanics

In this study, we employed the nonlinear respiratory mechanics that were expressed by time-invariant resistive and elastic components. The system was also expressed using the simplest serial R-C circuit, but the R_{rs} in Eq. (5) was replaced by R_1 and R_2 (Hirayama, 1995) (Fig. 2(b)). The driving pressure P(t) for the respiratory system was expressed as

$$\begin{aligned} P(t) &= \dot{V}(t)\cdot R_1 + \dot{V}(t)^2\cdot R_2 + V(t)\cdot E_{rs} \\ &= \dot{V}(t)\cdot\left(R_1 + \dot{V}(t)\cdot R_2\right) + V(t)\cdot E_{rs} \end{aligned} \tag{6}$$

where E_{rs} is again the lumped elastance of the total respiratory system, from the bronchi to the alveoli and thorax. R_l is the lumped viscous resistance of the flow through the entire respiratory system and R_2 is the second type of flow resistance that is proportional to the power of the flow rate. For comparison using the linear mechanics model of Eq. (5), the equivalent R_{rs} of Eq. (6) can be expressed as

$$R_{rs(eq)} = R_1 + \dot{V}(t)\cdot R_2 \tag{7}$$

Hirayama et al. (1995) analyzed airway pressure and flow by using the above nonlinear respiratory mechanics with the cost function containing a set of linear and nonlinear terms involving airway pressure depressed by a rapid increase in airway pressure and the peak flow rate. To compare the effect of nonlinear respiratory mechanics on the optimization indices in the optimal chemical-mechanical control model, we used their standard levels of the system parameters (R_1 = 12 cm-$H_2O\cdot L^{-1}\cdot s$, R_2 = 3 cm-$H_2O\cdot L^{-1}\cdot s$, and E_{rs} = 16 cm-H_2O/L) in this study in a continuous resistive loading (CRL) simulation with an imposed loading of $\Delta R_1 = 4$ from normal load (R_1 = 8 cm-$H_2O\cdot L^{-1}\cdot s$).

In current study, the airflow $\dot{V}(t)$ is further derived by breaking it into inflow and outflow air, $\dot{V}_{in}(t)$ and $\dot{V}_{ex}(t)$, respectively. Both optimized lung volume $V_{in}(t)$ and $V_{ex}(t)$ and airflow $\dot{V}_{in}(t)$ and $\dot{V}_{ex}(t)$ by using Fourth-order Runge-kutta with an estimation error Δt^5 and cumulative error Δt^4.

$$\dot{V}_{in}(t) = -\frac{R_{in1}}{2R_{in2}} \pm \sqrt{\frac{P_{in}}{R_{in2}} + \left(\frac{R_{in1}}{2R_{in2}}\right)^2 - \frac{E_{rs}}{R_{in2}}V_{in}(t)} \tag{8}$$

$$\dot{V}_{ex}(t) = -\frac{R_{ex1}}{2R_{ex2}} \pm \sqrt{\frac{P_{ex}}{R_{ex2}} + \left(\frac{R_{ex1}}{2R_{ex2}}\right)^2 - \frac{E_{rs}}{R_{ex2}}V_{ex}(t)} \tag{9}$$

4. Optimization Criteria

The optimal controller in our model is driven by both chemical and neuro-mechanical feedback signals (Fig. 1) through the coupling of the chemical cost (J_C) and the mechanical cost (J_M), which are represented by the chemical feedback signal quadratic coupler and the work-rate logarithmic coupler, respectively. The optimal control output is determined by the minimum of J. The fundamental hypothesis of the model is that a total cost (J) can be formulated to reflect the balance of a combined challenge due to the chemical and mechanical cost of breathing (Poon, 1987; Poon et al., 1992). The mathematical descriptions of the optimization indices have been detailed previously (Lin et al., 2012; Lin et al., 2013; Lin et al., 2014) and are outlined below in Eqs. (10–13):

$$J = J_C + J_M \tag{10}$$

$$J_C = \alpha^2\cdot\left(P_{aCO_2} - \beta\right)^2 \tag{11}$$

$$J_M = \ln\dot{W} \tag{12}$$

$$\begin{aligned} \dot{W} &= \dot{W}_I + \lambda\cdot\dot{W}_E \\ \dot{W}_I &= \frac{1}{T}\int_0^{T_I}\frac{P(t)\cdot\dot{V}(t)}{\xi_1^n\cdot\xi_2}dt \\ &\begin{cases} \xi_1 = 1 - \dfrac{P_{0.1}}{P_{max}} \\ \xi_1 = 1 - \dfrac{P_{0.1}}{P_{max}} \end{cases} \\ \dot{W}_E &= \frac{1}{T}\int_{T_I}^{T}P(t)\cdot\dot{V}(t)\,dt \end{aligned} \tag{13}$$

In Eq. (13), the total mechanical index is assumed to be a weighted sum of the inspiratory and expiratory indices, with a weighting parameter λ, and where $\dot{W}$, $\dot{W}_I$, and $\dot{W}_E$, represent the total respiratory, inspiratory, and expiratory work rate in kg·m/s, respectively. Efficiency factors ξ_1 and ξ_2 account for the effects of the respiratory-mechanical limitation and the reduction in the neuro-mechanical efficiency with increasing effort. The overall efficiency depends on 2 factors: the maximal isometric pressure (P_{max}) and the maximal rate of rise in the isometric pressure ($\dot{P}_{max}$). The respiratory period of a breathing cycle ($T = t_1 + t_2$, s) accounts for the inspiratory (t_1) and expiratory (t_2) durations of neural activity, whereas the parameter T_I describes the duration of mechanical inspiration, during which air flows into lungs for the inspiratory work of breathing.

5. Simulation Results and Discussion

Table 1: Parameters for mechanic loadings with linear and nonlinear respiratory mechanics models

Loading Simulations	Linear Respiratory Mechanics: Airway Resistance cm-H_2O/l/sec		Elastance cm-H_2O/l	Nonlinear Respiratory Mechanics: Resistance R_1 cm-H_2O/l/sec		Resistance cm-H_2O/l/sec	Elastance cm-H_2O/l
	R_{in}	R_{ex}	E_{rs}	R_{in1}	R_{ex1}	R_2	E_{rs}
NL	3.02	3.02	21.9	8	8	3	16
CRL	8.00	8.00	21.9	12	12	3	16
IRL	8.00	3.02	21.9	12	8	3	16
ERL	3.02	8.00	21.9	8	12	3	16

In the simulation of Rest condition, P_{ICO2} is set to be 0% and $\dot{V}_{CO_2}$ is set to be 0.2 (L/min). The simulation of CO_2 inhalation responses were performed by setting P_{ICO2} = 1%~7%. The system response to muscular exercise was achieved by varying $\dot{V}_{CO_2}$ within the range of 0.2~1.0 L/min. In our previous study applying linear respiratory mechanics on the optimal respiratory control model, the parameters for resistance and elastance were set at R_{rs} = 3.02 (cm-$H_2O \cdot L^{-1} \cdot s$) and E_{rs} = 21.9 (cm-$H_2O \cdot L^{-1}$), respectively, for normal loading. In simulating CRL, the inspiratory and expiratory airway resistances (R_{in} and R_{ex}) were increased to the intended levels of loading. The parameter values of the resistance and elastance for simulations performed in this study at rest and under loaded breathing (CRL, IRL, and ERL) with linear and nonlinear respiratory mechanics are summarized in Tables 1.

In Figure 3, the waveshapes of the optimized instantaneous respiratory signals, including P(t), $\dot{V}(t)$, and V(t), are illustrated and compared for simulations of CO_2 inhalation (Fig. 3(a)) and eucapnia (Fig. 3(b)) by using linear (left columns of Figure 3 (a) and Figure 3 (b)) and nonlinear (right columns of Figure 3 (a) and Figure 3 (b)) respiratory mechanics models. The simulations were performed with no load. In Figure 4~6, simulation results of respiratory resistive loadings, IRL, ERL, and CRL, respectively, are shown. In previous studies using the linear respiratory mechanics model, the model behaviors in no-load and loaded simulations were evaluated and determined to compare favorably with experimental findings (Poon, 1987; Poon et al., 1987; Poon et al. 2007; Haouzi & Bell, 2009).

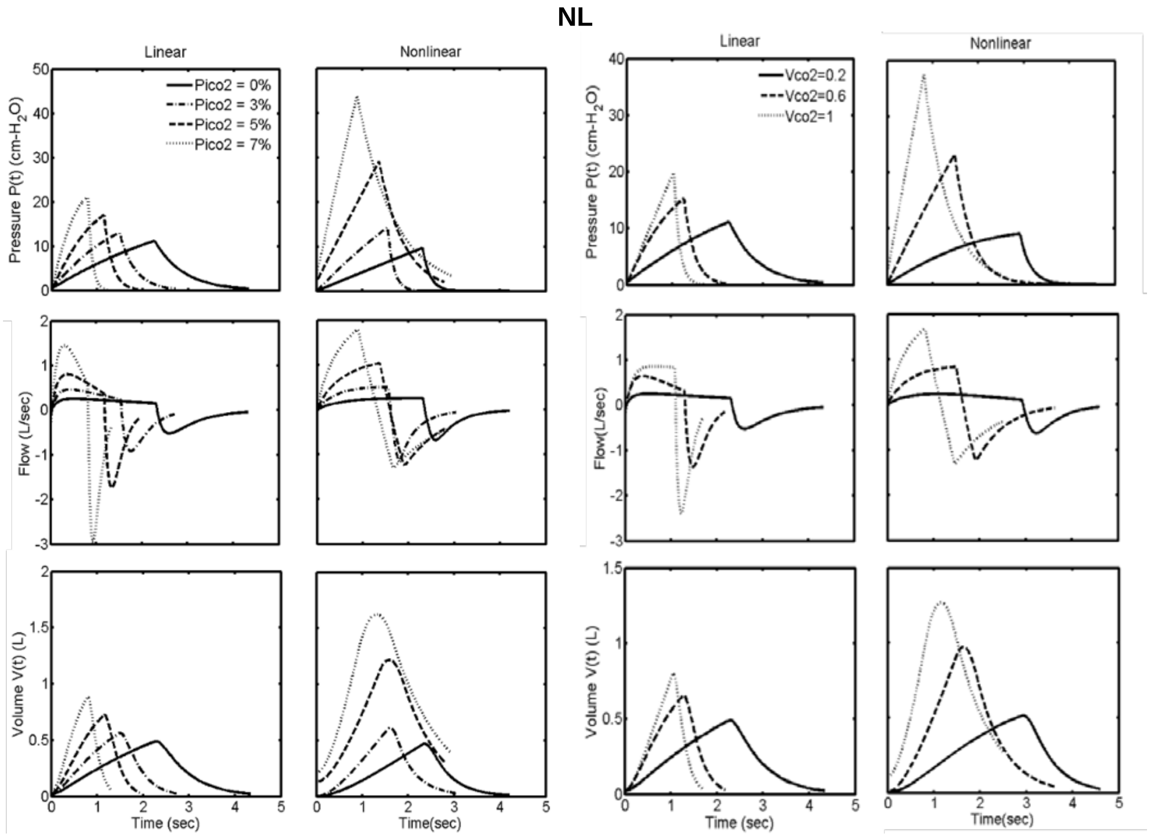
Under NL simulation of Figure 3, the linear mechanics model optimized the inspiratory phase of the P(t) with the increase rate showing a ramp-like shape for increased exercise input and a more convex shape for increased CO_2 inhalation. The nonlinear respiratory mechanics model optimized the inspiratory phase of P(t) in the same ramp-like fashion under both CO_2 inhalation and exercise conditions, but attained higher amplitudes and steeper rising rates compared with those attained with the linear model. The airflow during the inspiratory phase of the linear model was rectangular and showed a nearly constant flow rate during exercise with increased $\dot{V}_{CO_2}$, but became more peaked and convex and then decelerated toward the end of inspiration during CO_2 inhalation. By comparison with the nonlinear model, the airflow maintained a constant flow rate in the resting state but with a triangular profile in both the inspiratory and expiratory phases during exercise and CO_2 inhalation. The lung-volume profile obtained with the linear model retained a similar ramp-like behavior as the neuromuscular drive but with a higher peak (larger V_T) and a shorter duration (smaller T) during exercise and CO_2 inhalation. However, the nonlinear model achieved similar concave lung-volume waveshapes in both cases. Generally, the lung volume profiles predicted by the nonlinear model demonstrated higher amplitude compared with those by the linear model in both CO_2 inhalation and exercise simulations.

In the loaded simulation of IRL (Figure 4), the effect of CO_2 inhalation on the waveshape of P(t) became more significant than that in the NL simulation of linear model, while no major difference. The shape of the rising phase during resistance breathing of IRL was found to be more concave upward with enlarged amplitude. With the nonlinear model, the imposed IRL did not show much effect on P(t) in either CO_2 inhalation or exercise in comparison with the NL simulation. The airflow waveshapes of IRL also demonstrated similar behavior in both

CO_2 inhalation and exercise for the linear and nonlinear model. Compared with the linear model, the airflows of the nonlinear model tended to have an attenuated peak expiratory flow rate at high P_{ICO_2} and $\dot{V}_{CO_2}$ levels. In IRL simulation of the linear model, the amplitude of lung volume profile increased significantly with increased P_{ICO_2} in comparison with the NL simulation. However, we also found the increase of peak flow showed less significant in nonlinear model in IRL, compared with NL simulation, under CO_2 inhalation.t.

In the loaded simulation of ERL (Figure 5), the neuromuscular drive of the linear model exhibited similar responses to either increased CO_2 inhalation level or increased exercise input with enlarged amplitude and more convex waveshape. With the nonlinear model, the P(t) was found to explicit ramp-like waveshape with higher slope with increased P_{ICO_2} under CO_2 inhalation, while showing convex upward and sinusoidal waveshape with increased $\dot{V}_{CO_2}$ under exercise. With the ERL in linear model, the effects of CO_2 inhalation and exercise on the waveshapes of airflow rate and lung volume are similar to those with the IRL. Meanwhile, with the ERL in nonlinear model, we found that the effect of increased P_{ICO_2} and t $\dot{V}_{CO_2}$ on the airflow waveshape opposed to the observations depicted in the IRL simulation. As the P_{ICO_2} increased to 7%, the airflow waveshape turned to convex and became an ascending waveform, and as the $\dot{V}_{CO_2}$ increased to 1.0, the airflow resembled a sinusoidal waveform.

In the loaded simulation of CRL (Figure 6), the inspiratory phase of the neuromuscular drive of the linear model exhibited more convex waveshape with increased exercise input and CO_2 inhalation. The nonlinear model exerted no notable effects on the waveshape of P(t) during NL or CRL. Whereas the airflow in the linear model was more sinusoidal under CRL in both hypercapnic and eucapnic cases, airflow in the nonlinear model exhibited a ramp-like shape during inspiratory flow and was triangular during expiratory flow. The CRL of the nonlinear model once again did not affect the lung-volume waveshape markedly compared with the NL case.



(a) **(b)**

Figure 3: The optimal neuromuscular driving pressure (P(t), top row), airflow ($\dot{V}(t)$, middle row), and lung volume (V(t), bottom row) with linear (left column) and nonlinear (right column) respiratory mechanics under NL. (a) CO_2 inhalation (P_{ICO_2}=0%~7%); (b) Exercise ($\dot{V}_{CO_2}$=0.2, 0.6, and 1.0)

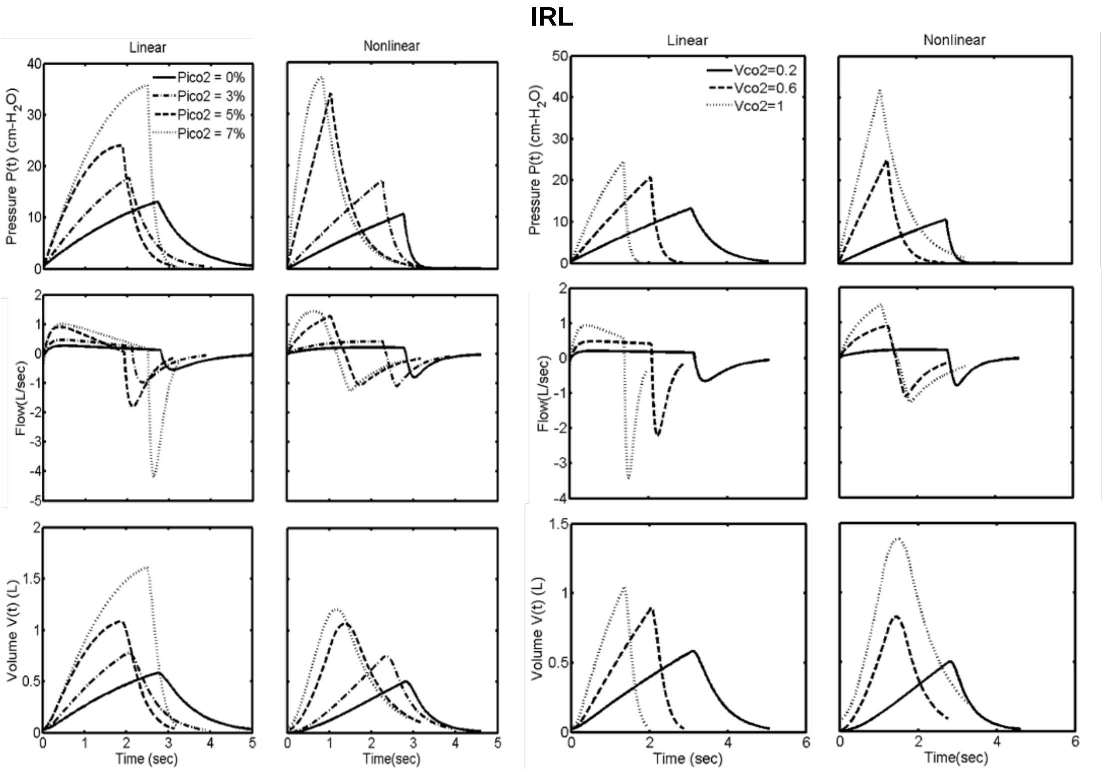


Figure 4: The optimal neuromuscular driving pressure (P(t), top row), airflow ($\dot{V}(t)$, middle row), and lung volume (V(t), bottom row) with linear (left column) and nonlinear (right column) respiratory mechanics under IRL. (a) CO_2 inhalation (P_{ICO_2}=0%~7%); (b) Exercise ($\dot{V}_{CO2}$=0.2, 0.6, and 1.0)

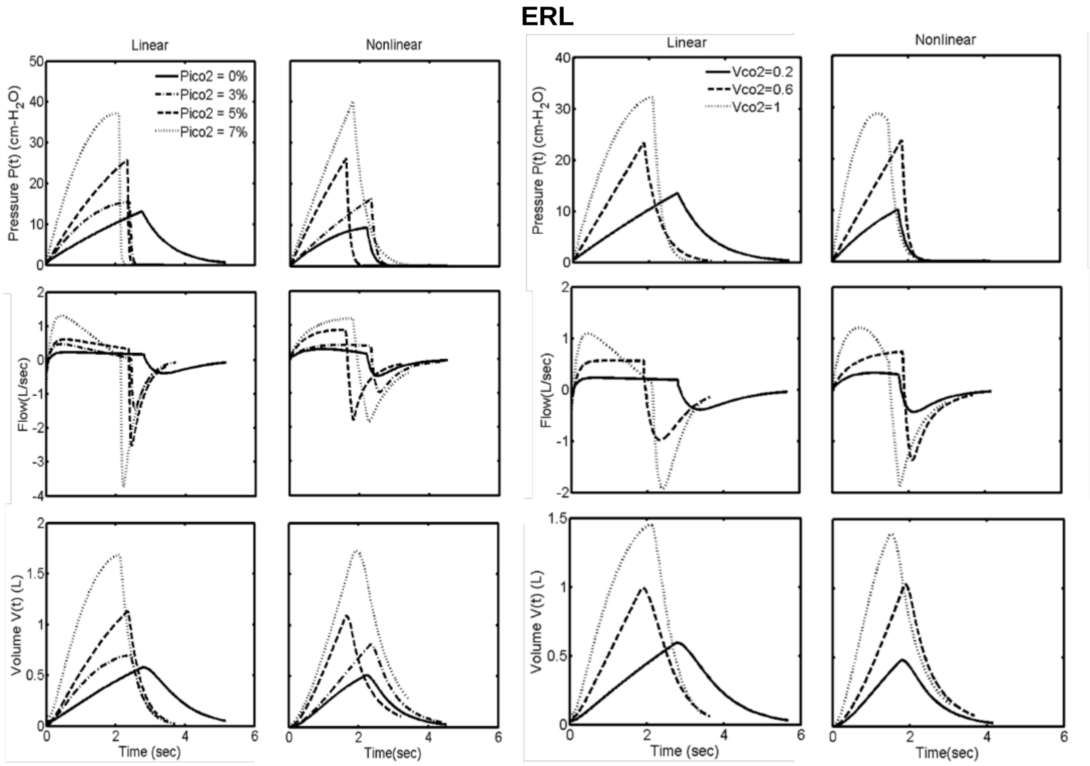


Figure 5: The optimal neuromuscular driving pressure (P(t), top row), airflow ($\dot{V}(t)$, middle row), and lung volume (V(t), bottom row) with linear (left column) and nonlinear (right column) respiratory mechanics under ERL. (a) CO_2 inhalation (P_{ICO_2}=0%~7%); (b) Exercise ($\dot{V}_{CO2}$=0.2, 0.6, and 1.0)

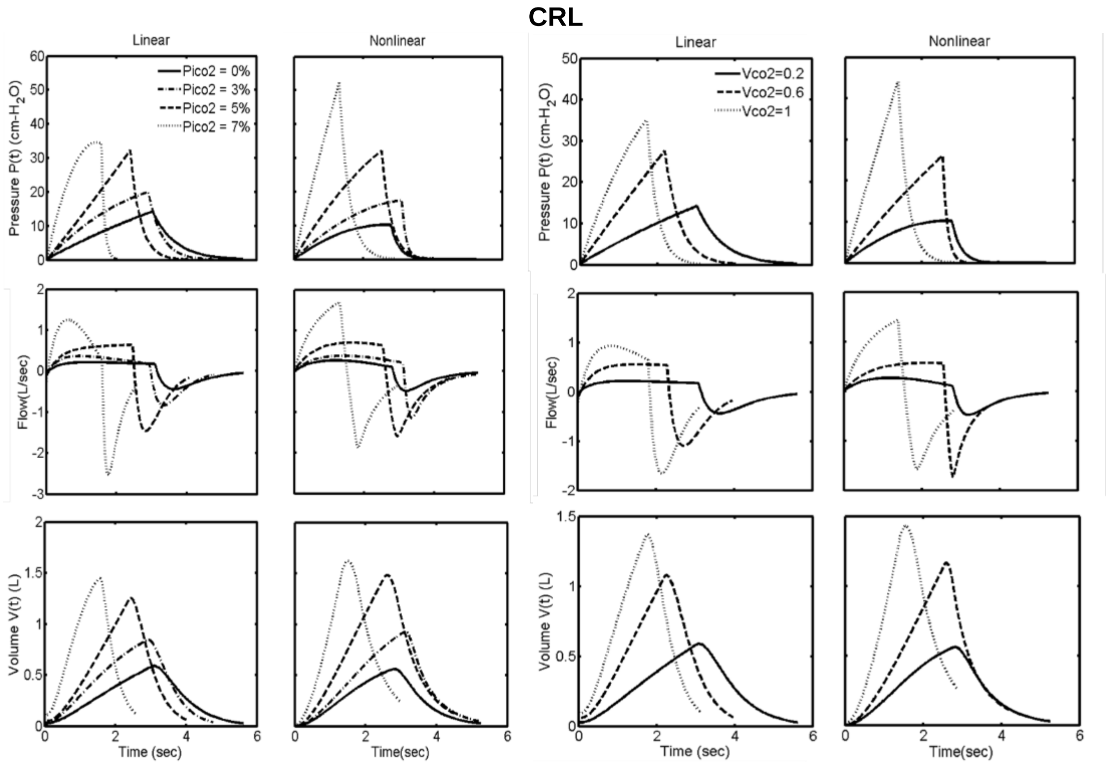
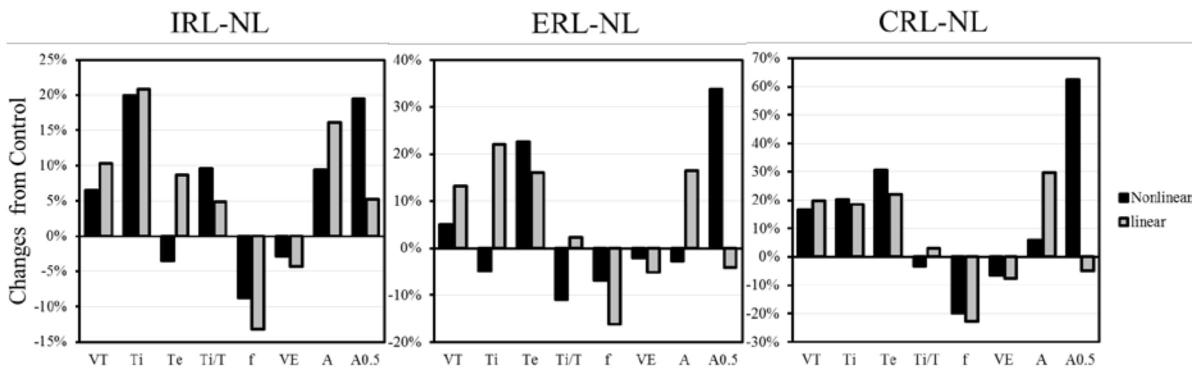


Figure 6: The optimal neuromuscular driving pressure (P(t), top row), airflow ($\dot{V}(t)$, middle row), and lung volume (V(t), bottom row) with linear (left column) and nonlinear (right column) respiratory mechanics under CRL. (a) CO_2 inhalation (P_{ICO_2}=0%~7%); (b) Exercise ($\dot{V}_{CO_2}$=0.2, 0.6, and 1.0)

In Figure 7, the loading effects, including IRL (Fig. 7.a), ERL (Fig. 7.b), and CRL (Fig. 7.c), on the optimized respiratory signals were converted to demonstrate the percentage changes of various respiratory patterns from controlled no load simulation for both linear and nonlinear models. The tidal volume (V_T), duration of inspiratory and expiratory phases of respiration (T_I and T_E), duty cycle (T_I/T), breathing frequency (f), minute ventilation ($\dot{V}_E$), peak amplitude of driving pressure (A), and the shape index $A_{0.5}$ which represents the percent of maximum amplitude of inspiratory pressure reached at 50% of T_I, under loaded simulation were derived and compared with those of normal load. Earlier experimental findings (Poon et al., 1987; Henke et al., 1988; Brack et al., 1998) showed an increased T_I, T_E, and V_T, and a decreased f with resistive loadings (IRL, ERL, and CRL). It appeared that the linear model showed consistently with experimental findings while the nonlinear model seemed to have opposed results with decreased T_E during IRL and ERL simulations. In comparison with the linear model, the loaded simulation of the nonlinear model also depicted a significant increase in $A_{0.5}$.



(a) (b) (c)

Figure 7: The percentage changes of respiratory patterns with (a) IRL, (b) ERL, and (c) CRL from controlled simulation of normal load (NL) at rest.

6. Conclusions

Human respiratory mechanics are often modeled as a lumped parameter R-C circuit to simplify the simulation in modeling human respiratory control. In current study, we used the nonlinear system employed by Hirayama et al. (1995), in which respiratory mechanics are represented by a lumped elastance of the volume, a viscous resistance of the flow through the total respiratory system, and a second type of flow resistance that is proportional to the power of the rate of flow. Instead of using a sinusoidal inspiratory airflow for the optimization using a criterion with 6 nonlinear terms (Hirayama et al., 1995), we applied the nonlinear respiratory mechanics model in the optimal chemical-mechanical respiratory control model that is proposed and verified (Poon, 1987; Poon et al., 1992; Lin et al., 2012; Lin et al., 2013; Lin et al., 2014) to obtain the optimal instantaneous respiratory signals and breathing patterns.

To evaluate the performance of nonlinear mechanics in the optimal respiratory control model, the model behavior under CO_2 inhalation of increasing P_{ICO_2} level (0%~7%) and muscular exercise of increasing $\dot{V}_{CO_2}$ output were simulated under normal loading and loading conditions, including IRL (inspiratory resistive loading), ERL (expiratory resistive loading), and CRL (continuous resistive loading). We examined the optimized respiratory signals, including the neuromuscular driving pressure, airflow, and lung volume profile, and derived breathing patterns: V_T, T_I, T_E, T_I/T, F, $\dot{V}_E$, A, and $A_{0.5}$.

Compared with the profiles in the linear model, the optimal neuromuscular driving profiles of P(t) and V(t) in the nonlinear model exhibited ramp-like waveshapes with steeper rising rates (larger a_1) and higher peak amplitudes (higher A and V_T) under hypercapnia and eucapnia conditions with both NL and CRL. But with IRL and ERL simulations, the both profiles (P(t) and V(t)) still retain a higher steeper rising rates but with similar peaks with increased P_{ICO_2} and $\dot{V}_{CO_2}$ levels.

Instead of resembling the inspiratory rectangular waveform during exercise and the descending waveform during CO_2 inhalation that were attained with the linear model, the nonlinear model showed triangular airflow waveshapes in both inspiratory and expiratory phases under eucapnia and hypercapnia. The inspiratory waveform in the nonlinear model was also unlike the sinusoidal or descending waveform obtained by the linear model and remained triangular and became more convex under NL and most resistive loading cases. However, we do find the optimized airflow became sinusoidal as $\dot{V}_{CO_2}$ increased to 1.0 under ERL simulation in nonlinear model. In most of the simulation cases with CO_2 inhalation or muscular exercise, the nonlinear model attain a lower peak expiratory flow rate, in comparison with the obtained airflow in linear model.

In this study, we compared the linear and nonlinear respiratory mechanics models with optimal chemical-mechanical respiratory control under CO_2 inhalation and muscular exercise conditions under NL and loaded simulations. It generally provides a framework for further exploiting the ventilatory control behavior of the nonlinear breathing mechanics to optimize respiratory signals and breathing patterns.

Acknowledgements

This study was granted by the Ministry of Science and Technology, R.O.C. (MOST 104-2221-E-451-005).

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

Evaluation of Risk Management Practices: Data Analysis of NHS England Hospitals

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Abstract

Risk management practices are applied in the National Health Service (NHS) England hospitals to reduce harm rates and to ensure safety. This study evaluates current risk management practices in the NHS England hospitals through highlighting non-compliance issues within the practice and through explaining board level risk priorities. All data were collected for selected (N=34) NHS England hospitals. Data were gathered from the NHS Litigation Authority (NHSLA) reports to reveal risk management problems and from Board Assurance Frameworks (BAF) to define top risks. Results from an external authority of the NHSLA show that local induction of staff is a major non-compliance issue for risk management practice with more than half of the hospitals having difficulties. Following that supervision of medical staff in training is the second highly observed deficiency. Results from hospitals' board level demonstrate that top risks in hospitals were regarding quality and performance issues. Additionally, most of the board level defined top risks were categorized as organizational and clinical-related risks. Within these, workforce issues and non-compliance with requirements are highlighted as top risks for organizational-related risks while Accident and Emergency (A&E) targets and treatment delays are prioritized as part of clinical-related risks. Financial deficit is also frequently defined at board level as a top risk for financial-related risks. Both the NHSLA and hospital board level assessments show that workforce related issues are still a major concern in hospital risk management practices. It is therefore a slight influence of an external authority (NHSLA) has been recognized on prioritization of board level defined risks.

Keywords

Risk, safety, risk management, hospital

1. Introduction

Prevention of adverse events in the healthcare sector is a growing worldwide concern (Clarkson et al., 2004). As much as one in three of the patients admissions are estimated to experience the adverse events (Landgrigan et al., 2010). This indicates that hospitals are potentially error-prone. However, this hazardous environment of hospitals can be reduced by risk management activities with also an effort to improve quality and to lower costs (P Barach & Small, 2000).

In the healthcare industry, risk management has been practiced as an essential part of hospital administration since the 1970s due to a healthcare insurance crisis in the USA (Kuhn & Youngberg, 2002). Then, the understanding of risk management moved to be quality and safety-centric. With the development of risk management methods and the reaching of safety maturity levels in other industries, safety awareness in the healthcare industry has also been developed (Eidesen, Sollid, & Aven, 2009; C Vincent, 2010).

Risk management is a combination of culture, structure and process which aims to promote continuous risk identification to take preventative actions, and to help decision makers with respect to resource allocation by increasing the awareness of safety in the organization (Garvey, 2009; Macdonald, 2004). In order to implement risk management practice, these 5 steps should be followed: (1) risk identification (what could go wrong?), (2) risk analysis (how bad is it and how often does it occur?), (3) risk evaluation (is there a need for action?), (4) risk treatment (how to treat it?), and (5) risk monitoring (how to control assessed risk?) (BS EN 31010, 2010; Haimes, 2009; HM Treasury, 2004; Kaplan & Garrick, 1981; Macdonald, 2004; Mullai, 2006; NPSA, 2006). Asking these questions leads individuals to understand the risks around them, and provides an opportunity to take action to avoid, reduce, transfer, or accept risks.

In the literature some studies focus on risk management in specific areas such as needle stick, falls, and moving and handling (Alan Card, Harrison, Ward, & Clarkson, 2012; Nunes, Santos, da Silva, Lourenço, & Carvalhais, 2015), and focus on specific weaknesses such as blaming and safety culture (Kitch, Ferris, & Campbell, 2008) observed in risk management practice. However, there is little research examining externally defined risk management deficiencies and board level defined risk priorities. Therefore, this study evaluates current risk management practices at NHS England hospitals through addressing three following questions: “what are the common deficiencies in current risk management practice?”, “what are the priorities of the NHS England hospitals in their risk management practices?”, and “does the NHSLA risk management assessment have an influence on hospitals board level risk prioritization?”.

2. Material and methods

2.1 Dataset used

The National Health Service Litigation Authority (NHSLA) was established in 1995 to resolve disputes, to improve risk management, to share lessons learnt and to improve safety for patients and staff (Department of Health, 2013).

In order to reveal the NHS England hospitals’ key deficiencies in their risk management practice and concerns regarding their top risks, a grey literature review was conducted by gathering data from the NHSLA risk management assessment reports for each hospital, and from hospital BAF notes via each hospital web-site. Risk management assessment reports were reviewed to define common risk management deficiencies. Also, BAF notes were reviewed to highlight each hospital’s top (strategic) 5 risks which have potential threats or losses on organizations or organizational plans (Allan & Beer, 2006).

2.2 Risk Categorization

Hazards and risks can be categorized in a variety of ways. Runciman *et al* categorize hazards into environmental factors, organizational factors, human factors, subject of incident factors, and drug, equipment and documentation (Runciman et al., 2006). Other classification schemes are also evident in the literature; for instance Niel-Laile *et al* divide generic hazards into 10 categories: regulation, medical, material, technical, human, professional, information system, management, logistic and commercial (Niel-Lainé et al., 2011). Vincent defines 7 factors that influence on clinical practice, namely: institutional context, organizational and management factors, work environment, team factors, individual factors, task factors and patient characteristics (Charles Vincent, Taylor-Adams, & Stanhope, 1998) while other research describes 6 incident contributory factors: patient, individual, task, team, work environment, and organizational management institutional factors (Rogers, 2002). Most relevantly, the risk register system in a teaching hospital categorizes risk assessment as clinical risks (e.g. risks associated with direct patient care), organizational risks (e.g. risks relating to non-clinical care), health and safety risks, and project management risks, and information risks.

Based on the teaching hospital categories and the top risks identified in the present study, board level defined top risks were divided into 6 categories: communication-related (e.g. partnership and patient experience), clinical (e.g. HSMR rate, treatment delays and A&E performance), information-related (e.g. quality of data), organizational (e.g. workforce and compliance with standards), financial (e.g. overspendings), and health and safety (H&S) related (e.g. falls) risks. Same classification scheme was also used to categorize the NHSLA defined non-compliance issues.

2.3 Sample selection

The most recent publicly available data were collected for selected hospitals. An adequate sample size for the analysis was calculated to be 34 (confidence level of 95% and precision level of 15%). 34 hospitals were randomly selected out of 160 NHS England hospitals ensuring that each region was adequately represented. Table 1 provides information about the hospital type (acute specialist, acute teaching, large, medium and small trusts) by regions (North, Midlands and East, London, and South).

Table 1 Characteristics of the selected hospitals

	North (n=10)	Midlands and East (n=9)	London (n=5)	South (n=10)
Acute Specialist (n=2)	1	-	-	1
Acute Teaching (n=8)	2	2	2	2
Large (n=10)	4	3	1	2
Medium (n=9)	2	3	2	2
Small (n=5)	1	1	-	3

3. Results

First, non-compliance issues are defined from the NHSLA risk management assessment reports to present deficiencies of risk management practices. Second, key findings from each hospital BAF report are given to highlight board level risk priorities.

3.1 The NHSLA results for the common deficiencies in risk management practices

Deficiencies in risk management practices observed in at least 3 hospitals are given in Figure 1. Training is the main challenge faced by hospitals in achieving better risk management practices and it is considered as an organizational-related issue. One in three hospitals have problems with inductions for temporary staff, almost one in five hospitals with inductions for permanent staff and approximately one in four hospitals with supervision training. The assessment of training is based on documentation (e.g. content of the training), implementation and monitoring to make sure all staff completed the training (NHSLA, 2013). Risk management training and consent training are also highlighted non-compliance issues within the assessed risk management practices. Other highlighted organizational-related issues are employment checks, health record keeping standards and training need analysis. The remaining top issues are predominantly clinical and health and safety-related. Among them, the most common weaknesses for clinical risks are found to be clinical handover of care, patient information consent and the deteriorating patient; the most defined non-compliance issues for health and safety risks are moving and handling, secure environment and slips, trips and falls.

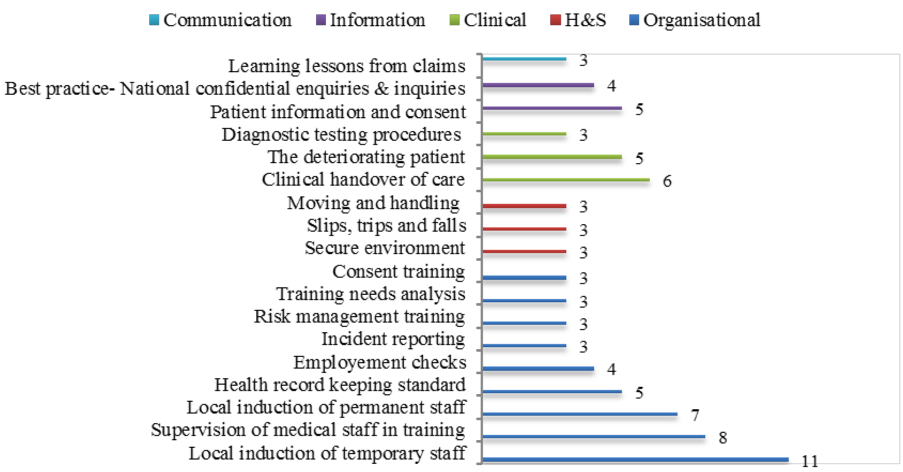

Figure 1 Non-compliant issues for 34 hospitals

In a nut shell, organizational-related issues (e.g. training and health record keeping standards) are the main deficiencies faced by hospitals on their risk management practices. Clinical-related issues (e.g. patient handover, patient information consent and deteriorating patient) and health and safety related issues (e.g. slips, trips and falls) are other key deficiencies in risk management practices. Having outlined the current key risk management deficiencies at NHS England hospitals, the next section describes what hospital board levels define as their risk priorities.

3.2. BAF results for prioritisation of risk

Top risks of hospitals were reviewed from BAF reports. Figure 2 illustrates board level defined top risks within the defined risk categories.

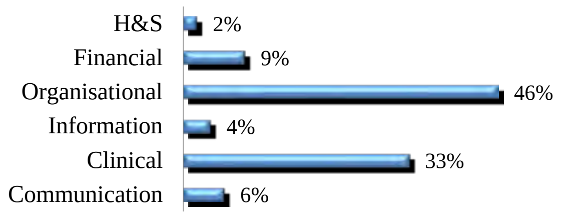

Figure 2 Board level defined top risks by risk category for n=34 hospitals

Hospitals at board level tend to prioritize organizational risks (46%) and communication-related risks (33%). Almost half of the hospitals top risks are related to workforce issues including staff capacity, staff vacancies, and workforce recruitment. Among top clinical risks, mortality rate, infection targets, A&E targets, patient discharge, patient handover, incidents and treatment delays are frequently defined at board level. Furthermore, patient complaints are defined by the boards in their top risks, coming under communication-related risks. Also, some other risks are determined under other risk categories. To give some examples of these risks: overspending is the most common financial-related risk, falls are the main health and safety risks, and e-care is seen as in the top risks for information related risks. Figure 3 demonstrates at board level defined top risks in at least 3 hospitals.

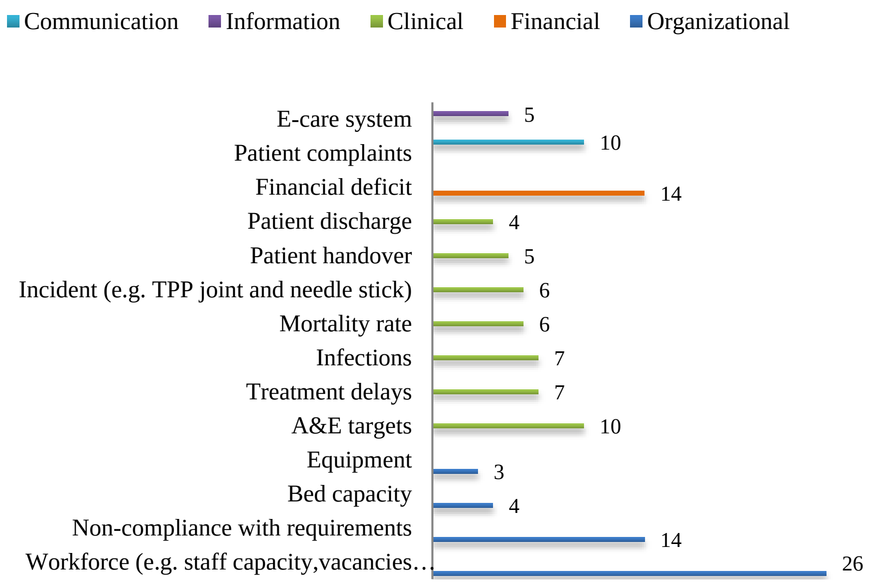

Figure 3 Hospitals board level defined top risks by given number of hospitals

4. Discussion

This study reveals that hospitals primarily define organizational-related risks as their top risks. Clinical risks are also frequently mentioned as top risks. Among clinical risks, a large number of risks address regulatory or national requirements which supports the idea that authorities have power to make changes or have influence on hospitals in terms of safety and quality applications (AJ Card, 2014; Gaba, 2010). To seek whether or not the

NHSLA assessments have influence on board level defined top risks, a comparison conducted between the NHSLA and BAF datasets. Although there is no direct influence was recognized among the collected data, there is still some indirect influence observed as in workforce-related issues defined by both the NHSLA and BAF reports. Having no direct influence can be explained by having no exact datasets between the NHSLA and BAF to compare except data of patient handover, training, discharge, patient falls and open culture. Also, there are some other external authorities that effecting decisions made by hospital board level such as the CQC (Care Quality Commission) and the NPSA (National Patient Safety Agency). Therefore, it is reasonable not to observe a strong relationship between the NHSLA and BAF datasets. As an example of indirect relationships, the NHSLA reports define hospitals' deficiencies on training when hospitals at board level focus on workforce and culture-related risks. As training is for staff, any staff related issues may result in problems with training. Also, any culture related issues may affect willingness of staff to take voluntary training.

The NHSLA risk management assessment reports highlight that induction training is the main concern to improve risk management practices, coming under organizational risks. Induction training is to integrate new employees into their working environment, to motivate them, to ensure they work in a safe environment, and to provide an overview of the organization and organizational culture. There are some statutory requirements for induction training. For instance, induction training covers the topics of fire safety, health and safety, manual handling, equality and diversity, and information governance (Coleman, 2013). Training in general is considered to be a factor that influence on safety culture of the organization (Farrington-Darby, Pickup, & Wilson, 2005; Glendon & Stanton, 2000). Additionally, safety training interventions reduce hazards and risks in the working environment and improve safety behaviors of all level staff (Dong, Entzel, Men, Chowdhury, & Schneider, 2004; Kinn, Khunder, Bisesi, & Wholley, 2000). A research also claims that mandatory training has significant influence on the workers' attitude by reducing incidents in their working environment in construction industry (Bahn & Barratt-Pugh, 2012). Furthermore, training of the healthcare staff is considered key to a better risk management practices, and training remains a serious issue for healthcare organizations (CQC, 2015; DoH, 2007; European Communities, 2009). It is therefore, training is an essential factor for safety in the organizations. However, researchers have claimed that healthcare practitioners are under-trained in safety (Alan Card, Ward, & Clarkson, 2012; Dul, Bruder, & Buckle, 2012; Pham et al., 2010; Youngson & Flin, 2010). Hence, it is understandable that external authorities are assessing hospitals risk management practices by measuring a variety of training practices.

Healthcare staff training is not the only problem that hospitals are facing, but they are also coping with workforce issues. Hospitals themselves define workforce issues as the main part of their top risks. The workforce-related issues in healthcare are also cited in the literature as a global problem (Gupta et al., 2015). Additionally, mortality rate (Chou et al., 2015), infection risks (Youssef, Novosad, & Winthrop, 2016), treatment delay (Verweji et al., 2015), and A&E targets are also widely mentioned in the literature as clinical risks all over the world and in our study as part of clinical-related top (strategic) risks. These highlighted clinical-related risks are explained as elements of key performance indicator factors (Chen & Wang, 2015; Gockel, Ahlbrand, Arras, Schreiber, & Lang, 2015; Harvey et al., 2015). As performance indicators are defined as part of quality measurement (Azami-Aghdash, Tabrizi, Sadeghi-Bazargani, Hajebrahimi, & Naghavi-Behzad, 2015; Mainz, 2003), it can be inferred that at hospitals board level defined risks are mostly quality and performance related concerns. Barach and Small state that reducing risks in healthcare is defined as an effort to improve quality by lowering costs (Barach & Small, 2000). Moreover, Lord Darvi defines quality with three dimensions: safety, effectiveness and patient experience, while quality in general is defined as a degree to meet needs of both stakeholders and systems (Berwick et al., 2013). Thus, quality in healthcare is understood as a more comprehensive discipline including safety. This comprehensive understanding of quality can be observed through this review as risk management mostly focusing on quality and performance issues.

However this study has some limitations. First, the study reviewed only a limited number of hospitals; therefore results may not represent risk management practices of all hospitals. However, even for a single hospital, it should be noted that different services may have different priorities and weaknesses. As an example of this, surgical wards and intensive care units aim for reliability with high quality whilst some others including blood transfusion, anesthesiology, and radiotherapy have safety as a priority (Amalberti, Auroy, Berwick, & Barach, 2005). Second, reports may not represent results for the exact time period. Still, the most recent publicly available data were used. Lastly, classification scheme may be biased because risks or issues may be defined under different categories or under multiple categories depending on the individual's perception.

5. Conclusion

This study drew attention to the common weaknesses in current risk management practices that were defined by an external authority (NHSLA), and risk priorities in hospitals that were determined at the board level of hospitals. Whilst staff safety training is still the main deficiency for risk management practices, workforce related risks are defined to be the main risk priority from the board level. Therefore an indirect influence of external authorities concerns on board level priorities is observable.

Further research can be carried out to understand the underlying reasons of defined weaknesses and prioritized risks within risk management practices.

Acknowledgments

This paper presents independent research funded by the National Institute for Health Research (NIHR). The views expressed are those of the authors and not necessarily of the NHS, the NIHR or Department of Health.

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Dynamic scheduling of generalized flowshop problems using mathematical programming

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The static scheduling approaches have been impractical in real-world scheduling problems because of the dynamic nature of the real production environments [1]. The aim of this study is to develop an effective solution procedure for a generalized flowshop scheduling problem in an automotive stamping company with predictive/reactive dynamic scheduling approach [2]. We consider the complete rescheduling strategy when an unexpected event happens (event driven) [1]. In order to solve the real-world scheduling problem, we develop an iterative mathematical programming approach inspired by decomposition techniques. The computational results show that the proposed method generates successful static schedules for real-world instances within minutes. On the other hand, the company spends 28 hours on planning and maintaining its weekly schedules. To mimic the real production environment and reflect the unexpected/planned interruptions accurately, we use the proposed solution method for predictive and reactive scheduling process, and regenerate current schedules when an interruption occurs. We use the historical weekly schedules of the company (company-executed) for comparison and demonstrate that the proposed method spends 504.4 seconds (8.4 minutes) to maintain the weekly production including interruptions, on average. In addition, the method generates shorter schedules (smaller makespan) corresponding to a 6.1% improvement and 8.7 hours of savings per week, on average.

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Comparison of dynamic scheduling approaches: Predictive/reactive scheduling vs. Robust proactive scheduling in a generalized flowshop environment

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The purpose of this study is to evaluate and compare two different kinds of dynamic scheduling policies [1] using a real-world scheduling problem in a stamping company that can be classified as a generalized flowshop problem. The interruptions in the considered pressline such as machine breakdowns and planned interruptions are examined statistically (in which machines they occur and their durations), and the distributions of interruptions are determined; thus, the artificial interruptions could be created and added to the weekly schedules at the beginning of the week. The weekly schedules are generated with these artificial interruptions by robust proactive scheduling [2], and as a second approach the predictive/reactive scheduling policy is considered. This policy generates the first schedule ignoring the interruptions, and reschedules the production process when an interruption occurs [1]. The weekly schedules generated by two different dynamic scheduling policies are compared to company-executed schedules with the aim of minimum makespan. The computational results show that the weekly schedules produced by the predictive/reactive scheduling approach are better than the schedules produced by robust proactive scheduling and by the company.

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MIP Model and Hybrid Heuristic Solution Method for Milkrun

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In this study, supplier milk-run problem solution methods are proposed. In the problem, there are heterogeneous vehicle fleet and multiple products. Order's and vehicles' volume and weight constraints are also considered in the problem. Developed MIP model solved the small sized problems optimally. For the large scale problems, another hybrid method is proposed. In order to compare algorithms, random generated data that fits uniform distribution is used. The comparison results validate the effectiveness of the proposed algorithms.

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Comparison of Neural Network and Wrapper Methods for Decision Making: Acceptance of Fabrics in Quality Control Process

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To maintain the competition in the global marketplace, quality control is playing crucial role in all industries. This study is focused on the acceptance process of fabrics in textile industry. This process, which is made by manually is required to be transformed into automated inspection because of high inspection cost and boredom of the process. In this study, there are four different features that determines the acceptance of incoming fabric lots. To compare hybrid genetic algorithm as wrapper method, RBF (Radial Basis Function) and LMS (Least Mean Square) as neural network methods, data more than a thousand was taken from the real-life production process. And also the results of Naïve Bayes and Ibk methods were found using Weka, which is well-known machine learning software. The results show that RBF and wrapper method find similar classification accuracies.

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Genetic Algorithm Based Hybrid Solution for Feature Selection

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In order to solve feature subset selection problem, a hybrid genetic algorithm method is proposed in this study. Solution technique in the method can be called as embedded. In the algorithm, after data processing, the initial pool is generating for genetic operations. Local search is applied for each chromosome to improve objective function value. k-Nearest Neighbor classifier is adopted to find total error and fitness function value. Genetic operations are conducted to get better values until the last generation. In order to validate the algorithm, datasets from UCI database were analyzed. The response of different methods and proposed method is compared in the study and the results show the effectiveness of the developed algorithm.

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Hybrid Method for Large Scale Scheduling Problem

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Hybrid method to solve large scale scheduling problem is proposed in this study. The proposed algorithm is embedded to local search method to improve the results. In the problem, there are unrelated parallel machines and sequence dependent setup times. Additionally, jobs can be divided into sub jobs to deliver the orders on time. Machine eligibility is another feature of the studied problem. The proposed algorithm outperformed by a considerable margin the existing method.

Acknowledgements

The authors thank the Planning Department of Boyteks Trade Co./Bursa for their collaboration.

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The Human Physical and Cognitive Roles in Automation Systems

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The fast evolution in computer technology has transformed the course of our daily lives by giving an oppurtunity to automate many aspects of the man-machine systems. For almost every man-machine system, whether in the aviation industry, medical systems, industrial process control, or just for use in leisure activities or the home environment, it is possible to see many automated systems and devices that have replaced the human component as a key element. This new form of human-machine interaction has caused a major change in the way people use and work with automation technology. So, human factors are also taken into consideration in designing automated systems and their components to enhance human-machine interfaces. This review aims to ouline a) the basic and applied knowledge of automation, b) the human physical and cognitive role in automation systems and c) the human cognitive performance as guidelines for designing of automation system presenting ergonomic properties. Automated systems have reduced the burden of excessive physical and cognitive demands imposed upon human operators. However, they have resulted in several behaviors related problems such as a loss in situation awareness, increased mental workload, monitoring inefficiency, and inability to revert to manual control under systems malfunction. Hence studying automation from a cognitive point of view for the function allocation between humans and machines, and for solution of main problems encountered within the human-automation interaction were also reviewed. This review will provide the overview of this emerging area, as well as the new and future areas of application.

Keywords
Human-automation interaction, adaptive automation, cognitive science, function allocation

Acknowledgements
Acknowledgement of funding support and/or any other kind of assistance should be contained in an "Acknowledgements" section (this section should have no section number).

Biography

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Proceedings of the Global Joint Conference on Industrial Engineering and Its Application Areas 2016, Istanbul, Turkey, July 14-15, 2016

The Factors Affecting Job Satisfaction in Pharmaceutical Industry: A Turkish Company Application

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Abstract

Nowadays companies are giving more importance to their workers, because of job satisfaction of workers affecting performance of company positively. While workers have higher job satisfaction their efficiencies and company performance increases respectively. Thus job satisfaction is an important concept for companies. Although different sectors have the same kind of job satisfaction parameters, their importance levels and orders are changing against to the sector. This study focuses on the criteria for job satisfaction in pharmaceutical industry workers by using pairwise comparison questionnaires. The main 14 factors that are affecting job satisfaction evaluated in this study are job characteristics, managerial approaches, wage, career opportunities, appreciated by managers, working conditions, position, relationship with colleagues, employment security, development opportunities, organizational culture, role ambiguity, role conflict, and social opportunities.

Keywords

Job satisfaction, job satisfaction factors, pairwise comparison, pharmaceutical industry

1. Introduction

Job, organizational environment that took place in a certain time frame, bringing together diverse relationships and the fee is undertaken efforts to produce goods and services. Satisfaction is the emotional response format (Sevimli and Iscan, 2005). Employees having many experiences with working environment and company they are in. With these experiences the attitudes of workers develop against to their jobs and company they are within. Job satisfaction is a general sense of physical and mental consequences of these attitudes and represents the employees are in good condition (Oshagbemi, 2000a).

In this study we tried to find the pharmaceutical companies workers job satisfaction level with applying pairwise comparison questionnaires. The questionnaires are made with 23 white collar workers in a pharmaceutical company in Turkey.

2. Literature

There are many description of job satisfaction in literature. Some of these descriptions can be summarized as:

- Job satisfaction is the emotional response to employees' work against (Weiss, 2002).
- Job satisfaction, physical and social conditions of workers, depending on the degree of positive or negative feelings against to their jobs (Schermerhorn et al., 1994).
- Job satisfaction is a reaction against the individual's working environment (Berry,1997).
- Besides physical and mental health of employee, job satisfaction is a sign of physiological and psychological senses. (Simsek et al., 2003).
- Job satisfaction, work experiences against employees' work and the evaluation results are outgoing and positive emotional expression (Testa, 1999).
- Job satisfaction derived from work with the material interests of employees enjoy working together as colleagues and work alanine bring about happiness it provides stands (Bingol, 1996).

There are three important aspects of job satisfaction. First, job satisfaction, a kind of situation occurs against emotional reactions that occur in the business environment (Locke, 1976). Second, job satisfaction, usually output is related to the extent meet expectations (Vroom, 1964). Third, job satisfaction, represents many positions on the other. These features generally work, wages, promotion opportunities, management style, colleagues and so on. the attitudes (Smith, 1969).

Job satisfaction is not a static phenomenon. Thus individual or business with a number of other factors job satisfaction or dissatisfaction can occur (Lam, 1995). Therefore, factors that can be addressed individually and depending on the job or work environment that can be classified as environmental factors (Crossman and Abou-Zaki, 2003).

2.1. Individual factors

Individual factors can be described as, gender, personality, educational level, age-experience, degree, and marital status. In the literature there are studies focused on effects of individual factors on job satisfaction.

Gender: In terms of gender balanced group of individuals, employee satisfaction is higher when compared to working in groups dominated by one gender (Fields and Blum, 1997). The results are not directly on the job satisfaction is only possible to say that sex is generally regarded as an indirect effect on the job satisfaction (Oshagbemi, 2000b).

Personality: The work of the employees and the expectations of all life is related to their personality (Ozdemir, 2006). Visionary people cannot be satisfied because a lot of talent on expectations (Sevimli and Iscan, 2005). It is found that over authoritarian and repressive personality of the employers, reduces the job satisfaction (Ozdemir, 2006).

Educational level: Generally higher level of education of employees' job satisfaction was found to be higher than less educated workers (Baysal, 1981). While employees compare their education and gain levels with others gains and positions and gain levels, if they find equality or more satisfaction higher than the others (Uyargil, 1988).

Age and experience: Studies, showed that a positive correlation between age and job satisfaction (Hickson and my Oshagbemi, 1999). The reason is that, as a result of the increased experience increased employee performance and thereby increase the employee's job satisfaction (Groot and Brink, 1999). Studies conducted in five countries, older workers, young workers from their work showed that more than the satisfaction (Davis, 1988).

Degree: While seniority increases, the employee also be a reduction in expectations and, therefore, there is an increase in the level of satisfaction (Hunt and Saul, 1975).

Marital Status: Various studies are shown that married employees have more job satisfaction than single employees (Khaleque and Rahman, 1987). Satisfaction level of the single employees are increased when they are get married (Martin, 1999)

2.2. Environmental factors

Environmental factors that are affecting job satisfaction evaluated in this study are job characteristics, managerial approaches, wage, career opportunities, appreciated by managers, working conditions, position, relationship with colleagues, employment security, development opportunities, organizational culture, role ambiguity, role conflict, and social opportunities.

Job characteristics: If a job comes the interesting and innovative people so attractive and increase the job satisfaction (Erdogan, 1996). In addition, the optional employee job satisfaction and job characteristics are realized when it fits together. This adaptation takes place at that rate regardless of how much is job satisfaction (Ozgen et al., 2005)

Managerial approaches: The executive director for the type of work for the human type is that leads to higher job satisfaction. According to executives who helped in achieving goals for the work of subordinates’ managers to work; rise, wage increases are perceived as people who help to reach for the award and performance. On the other hand, people facing managers of managers who steered intimate relationships; Addressing the employees' personal problems; employees' personal interests are perceived as people who are aware. Ultimately, this situation has an impact on employees' level of satisfaction. manager as the person providing the employees to participate in decision perceptions and show them the way which leads to an increase in the level of satisfaction (Yousef, 2000).

Wage: The findings show that both physiological and security needs of the individual's wages reveals seen as a tool to saturate other needs in both a higher level. In addition, a symbol of success wages by employees is perceived as a source of recognition and similar variables. The feeling that a payment equivalent to their doors to people's success, their success will affect in a negative way and thus also reduce the level of satisfaction they will charge (Gordon, 1999).

Career opportunities: Promotion, is one of the important factors that encourage people to work. It was observed that people try the possibilities of progress in the company and have a positive impact on the level of satisfaction is the reward (Sevimli and Iscan, 2005).

Appreciated by managers: The overriding moral direction and encouragement is an important tool for all employees. Made by people which appreciated the importance of the work, providing a great employee satisfaction (Incir, 1990). People value the business had given them, it is easier to be satisfied if they know that he or she has the necessary qualities to do the job (Erdoğan, 1996).

Working conditions: Be in good physical working conditions and stress-free work environment affect employee job satisfaction positively (Edvardsson and Gustavsson, 2003). Workplace temperature, humidity, ventilation, lighting and noise levels, hours of work and rest breaks, workplace location, factors related to the work environment, such as cleanliness and quality of the workplace are to impact on job satisfaction (Bozkurt and Turgut, 1999).

Improving working conditions will increase the efficiency of both the employee and the employee will be given the perception of self-worth as a result of the employee's job satisfaction (Erdil et al., 2004).

Position: Socially in higher-level occupations, more job satisfaction is achieved (Davis, 1988). In studies on the subject (Hickson and Oshagbemi, 1999), it was determined that higher job satisfaction than or of the status of employees who have managerial titles that do not have such a profile of those in high positions or working in low-status jobs.

Relationship with colleagues: Business environment, meets the social needs of the individual. It therefore has a significant influence on satisfaction or dissatisfaction with the relationship with colleagues (Davis and Newstrom, 1998). A study conducted in the UK, tested the relationship between behaviors of colleagues and job satisfaction. The result of frequency analysis has shown that the positive relationship between job satisfaction and colleagues behaviors (Oshagbemi, 2000).

Employment security: Job security is vital for employees. As long as the employee until the hardworking and successful in exceptional circumstances if given the assurance that the job losses, the employee will work more peaceful. Occupational peace, is an important factor that increases the job satisfaction (Akinci, 2002).

Development opportunities: Employees need both professional and personal in the sense that they carry constantly desire to improve. The main reason for this is to be able to advance their careers. In other words, the company offered employees training or self-development opportunities is a tool for progress, which is an important element of job satisfaction (Akat, 1994).

Organizational culture: Organizational culture encompasses almost everything within the organization. Basic assumptions, beliefs, values, behaviors, practices, symbols and may include issues such as technology (Livari and Huisman, 2007). Employees when they adopt, and they know the values and norms of the organization, and so we are acting with a sense of job satisfaction levels increase.

Role ambiguity: Individuals that do not know what the business will do what is due to whom he is accountable cases are experiencing job dissatisfaction (Ozkalp, 1995). Accordingly, the intense stress of working in a high level of uncertainty role, anxiety, fear and hatred, decreasing job satisfaction, loss of self-confidence and results in low productivity (Kececioglu, 1998).

Role conflict: Role conflict is simultaneously a role than the one of the necessary role required other more embrace the individual as non-compliance of the role of personality traits assumed cases, role conflict occurs with a position to fill more than one role (Tekarslan et al., 2000). If individuals face to role conflict, they cannot show the desired behavior is reduced performance and this causes them to feel themselves unsuccessful. Accordingly, the individual's self-confidence is declining, is increasingly alienated away from work. These negative results, it causes the sensation of living does not work, to demoralize and reduce the level of satisfaction (Lui and Ngo, 2001).

Social opportunities: In addition to traditional payment systems and bonus programs, performance based incentives for work exceeding the expectations of satisfactory payment and also profit-sharing plans and profit sharing plans are also available (Erdil et al., 2004).

2.3. The Benefits of Job Satisfaction

According to the understanding of modern management, performance, profitability, just as the success of the organization and the show, according to variables such as market share or tax is not based on financial data it should be measured with the human dimension. In terms of job satisfaction, organizations must have a social responsibility and ethical requirements before everything (Erdogan, 1994). The higher the morale of the employees, the employees and work organization that makes a positive impact (Sevimli and Iscan, 2005).

- A person with good morale, fulfilling the mission of energy and enthusiasm.
- Those who are willing to work for jobs.
- Employees in the workplace have shown outstanding effort in difficult circumstances.
- Employees are required to cooperate in accordance with the objectives of the workplace.
- Employees they feel loyalty to managers and workplace.
- High morale, absenteeism and labor turnover also serves on the positive effects. High morale, reduce staff turnover and absenteeism. Accordingly, the costs incurred are decreasing.

3. Application

This study is made on white collar employees of a pharmaceutical company in Turkey. The pairwise comparison questionnaire applied to 2 women and 21 men where 73.9% are age between 26-40 where details can be seen on the Table 1. Pairwise comparison questionnaires are evaluated by using Super Decisions software which is developed by Thomas Saaty.

Table 1: Demographics of employees attended to the study.

Demographics		**Total**	
		n	**%**
Gender	Women Men	2 21	8.7 91.3
Educational Level	Middle School High School College Under Graduate	1 6 5 11	4.3 26.1 21.7 47.9
Ages	15-25 26-40 41-50 51- over	1 17 4 1	4.3 73.9 17.5 4.3
Marital Status	Married Single	16 7	69.6 30.4
Position	Manager Worker	5 18	21.7 78.3
Employement duration in the company	< 1 1-5 years 6-10 years 11-15 years	3 7 8 5	13.0 30.4 34.9 21.7
Time span of working life	1-5 years 6-10 years 11-15 years 16	3 3 9 8	13.0 13.0 39.1 34.9

4. Results of Analysis

Analysis are grouped in four section. First, data analyzed by whole information without regarding any demographics. Consistency ratio for this analysis is 0.01764 which is less than 0.1 shows that data is consistent. Four of the important factors affecting job satisfaction are found as employment security, social opportunities, wage, development opportunities. Detailed graphics of factor weights can be seen in Figure 1.

Name	Normalized
C9 Employment Security	0,1577428
C14 Social Opportunities	0,1051451
C3 Wage	0,0974491
C10 Development Opportunities	0,0913848
C8 Relationship with Colleagues	0,0701637
C7 Position	0,0672541
C6 Working Conditions	0,0612370
C4 Career Opportunities	0,0595890
C12 Role Ambiguity	0,0527990
C5 Appreciated by Managers	0,0525629
C13 Role Conflict	0,0518614
C2 Managerial Approaches	0,0489075
C11 Organizational Culture	0,0428944
C1 Job Characteristics	0,0410093

Figure 1: Weights of factors affecting job satisfaction for all company

Secondly, educational level of employees is taken care. When we group the applicants into who has BSc. level and above versus applicants who don't have any BSc. Consistency ratio for these analysis is 0.01863 and 0.03605 which are less than 0.1. Details can be shown in Figure 2.

Name	BSc. Normalized	Not BSc. Normalized
C9 Employment Security	0,1695378	0,146135829
C10 Development Opportunities	0,118713882	0,07066327
C14 Social Opportunities	0,094500434	0,112942355
C3 Wage	0,081993283	0,111323671
C7 Position	0,067338449	0,065106803
C13 Role Conflict	0,063555072	0,041807409
C6 Working Conditions	0,062294969	0,059743943
C12 Role Ambiguity	0,061996086	0,044189516
C8 Relationship with Colleagues	0,060754843	0,076947389
C4 Career Opportunities	0,057109273	0,061053963
C2 Managerial Approaches	0,046009534	0,050956538
C1 Job Characteristics	0,042335146	0,040067982
C5 Appreciated by Managers	0,037832058	0,069049223
C11 Organizational Culture	0,036029169	0,050012108

Figure 2: Weights of factors affecting job satisfaction against to educational level

In Figure 3 effect of managerial difference can be seen easily. Consistency ratios for these groups are 0.03 and 0.05 respectively where analysis are consistent.

In Figure 4 effect of job satisfaction criteria for employment duration in the company are divided into two groups, where between 1-5 years and more than 6 years. Consistency ratios are 0.02911 and 0.0242 respectively.

All consistency rations are less than 0.1 and this means that all of the analysis are consistent and acceptable.

Name	Manager Normalized	Worker Normalized
C9 Employment Security	0,166147124	0,148876167
C10 Development Opportunities	0,09206705	0,086245607
C4 Career Opportunities	0,089565647	0,050136807
C3 Wage	0,086507321	0,088222258
C7 Position	0,082204813	0,060386204
C12 Role Ambiguity	0,067032009	0,057395983
C13 Role Conflict	0,063162536	0,047877825
C1 Job Characteristics	0,061299012	0,036179094
C14 Social Opportunities	0,053417199	0,121769503
C5 Appreciated by Managers	0,050409173	0,078358778
C6 Working Conditions	0,049276318	0,062883055
C11 Organizational Culture	0,049143683	0,039471719
C2 Managerial Approaches	0,047032223	0,043552577
C8 Relationship with Colleagues	0,042735892	0,078644421

Figure 3: Weights of factors affecting job satisfaction against to position

Name	Less than 5 years Normalized	More than 6 years Normalized
C9 Employment Security	0,166839111	0,147629516
C14 Social Opportunities	0,132350615	0,088025102
C10 Development Opportunities	0,101956749	0,082777433
C3 Wage	0,08985746	0,101605176
C8 Relationship with Colleagues	0,072513334	0,067834195
C7 Position	0,066068178	0,06937371
C13 Role Conflict	0,059431954	0,045846399
C12 Role Ambiguity	0,056886897	0,048840041
C6 Working Conditions	0,055739019	0,064549642
C4 Career Opportunities	0,051764171	0,065391923
C2 Managerial Approaches	0,04184142	0,05507658
C5 Appreciated by Managers	0,041547689	0,062069856
C11 Organizational Culture	0,031827214	0,052602851
C1 Job Characteristics	0,031376191	0,048377576

Figure 4: Weights of factors affecting job satisfaction against to employment duration in the company

5. Discussion and Conclusion

For all analysis employment security is emerged as most important job satisfaction factor in the company. The other factors are depending on educational level, position and employment duration in the company.

When we compare the educational level the other most important factors for above BSc. are development opportunities, social opportunities and wage. Important factors for job satisfaction for not BSc. graduated applicant are differing with above BSc. applicants. These are social opportunities, wage and relationship with colleagues which are differs.

Comparison with respect to position in the company, between managers and workers (non-managers), for managers: development opportunities, career opportunities and wage but for workers; social opportunities, wage, development opportunities in order.

When take into account duration in the company, important job satisfaction factors are deferring in order but they are the same factors. For the employee working less than five years are: social opportunities, development opportunities, wage. For the employee working more than six years are wage, social opportunities, development opportunities.

For improve the job satisfaction, the company must be give priority to these factors explained above. First of all, employment security is the most important factor at all. Then social opportunities, development opportunities, wage, career opportunities, relationship with colleagues factors have to be take in care mostly.

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Biography

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