ICIL 2016

AGH University of Science and Technology

International Center for Innovation and Industrial Logistics

ICIL ZAKOPANE 2016

13th International Conference on Industrial Logistics
28 September - 1 October Zakopane, Poland

ICIL 2016

Conference Proceedings

Faculty of Transport and Traffic Science, Zagreb, Croatia

COPPE, Federal University of Rio de Janeiro, Brazil

Vaasan yliopisto
UNIVERSITY OF VAASA

Unicesity of Zagreb
Faculty of Mechanical Engineering and Naval Archtecture

Honorary Patronage

Marshal of the Małopolska Region
Jacek Krupa

MAŁOPOLSKA

Mayor of Zakopane
Leszek Dorula

Zakopane

Sponsor

F.H.U. 'MEDEX'

ICIL 2016

AGH University of Science and Technology

International Center for Innovation and Industrial Logistics

ICIL ZAKOPANE 2016

13th International Conference on Industrial Logistics
28 September - 1 October Zakopane, Poland

ICIL 2016

Conference Proceedings

Faculty of Transport and Traffic Science, Zagreb, Croatia

COPPE, Federal University of Rio de Janeiro, Brazil

Vaasan yliopisto
UNIVERSITY OF VAASA

Unicesity of Zagreb
Faculty of Mechanical Engineering and Naval Archtecture

Honorary Patronage

Marshal of the Małopolska Region
Jacek Krupa

MAŁOPOLSKA

Mayor of Zakopane
Leszek Dorula

Zakopane

Sponsor

F.H.U. 'MEDEX'

ICIL 2016

Editor:

Tadeusz Sawik

Publisher:

AGH University of Science and Technology, Poland

Organizer:

AGH University of Science and Technology, Poland
International Centre for Innovation and Industrial Logistics

Technical Editor:

Katarzyna Gdowska, Roger Książek

Printed in:

ALNUS Sp. z o.o – 80 copies

Each paper has been reviewed by at least two reviewers. The accepted versions of all papers are presented in the form which is delivered by authors. The Organizer is not responsible for statements advanced in papers or spelling and grammar irregularities.

ISBN 978-83-62079-06-3

SCIENTIFIC/REVIEWING COMMITTEE

ORGANIZING COMMITTEE

EDITOR'S FOREWORD

As conference chair, this is my pleasant duty to present this publication, which contains the papers from the 13th International Conference on Industrial Logistics – ICIL 2016.

The conference took place in Zakopane, Poland, from September 28 to October 1, 2016. It was hosted by the Faculty of Management, AGH University of Science and Technology (Kraków, Poland) and by the International Centre for Innovation and Industrial Logistics (Brazil). The International Centre for Innovation and Industrial Logistics (ICIIL) is a non-profit professional association that has been developing an integrated view of Industrial Logistics, as well as sharing and exchanging ideas and research results among students, researchers, academics and industrialists.

The biannual International Conference on Industrial Logistics (ICIL) is the main mean to attain these objectives worldwide, moving from France 1993 to Brazil 1995, USA 1997, Russia 1999, Japan 2001, Finland 2003, Uruguay 2005, Lithuania 2006, Israel 2008, again Brazil 2010 and Croatia 2012 and 2014.

The ICIL 2016 conference features a multidisciplinary program that brings together experts from academia and industry to consider a broad range of logistics and supply chain management research and applications. One of the major roles of the conference was to provide a platform for bridging the gap between theory and implementation of logistics decision-making.

A variety of submissions for the conference came from 17 countries from 4 continents, which makes this conference a truly international meeting place to share expertise and experiences, and build professional network by meeting new people and reconnecting with colleagues. After the review process over 43 papers were accepted for the final program.

And, finally, I would like to express sincere gratitude to all those without whom the handling and organizing of this conference would have been impossible. In particular, it has been a pleasure to work with Katarzyna Gdowska, Roger Książek and Joanna Marszewska. On behalf of the organizing committee, I wish that all of you take the opportunity of attending ICIL 2016 to renew friendships and forge new ones, and that, you are able to enjoy your stay in Zakopane, capital of Polish Tatra Mountains.

Prof. Tadeusz Sawik, PhD, ScD
AGH University of Science and Technology
Faculty of Management
Kraków, Poland

TABLE OF CONTENTS

INVITED SPEAKERS

Erwin Pesch **XI**
Recent adavances in intermodal transport optimization

Zilla Sinuany-Stern **XII**
Factors effecting police station efficiency: DEA in police logistics

Waldemar Kaczmarczyk **XIII**
Does scheduling really have an impact on machine utilisation in flow shop systems?

Alain Haurie **XIV**
The logistics of sustainable regional energy systems

CONFERENCE PAPERS

Tautvydas Bargelis, Algirdas Bargelis **1**
Modeling of industrial logistics functions for order-based manufacturing companies

Esther A. Barreto O. , Gilberto J. Hernández G. , María J. García G., José G. Hernández R. **12**
Security & Safety (S&S) and the logistics business

Maciej Bielecki, Magdalena Hanczak **24**
Evaluation of the selected aspects of logistic efficiency of a product – an example of a production enterprise

Jerónimo De Burgos J., María J. García G., Gilberto J. Hernández G., José G. Hernández R. **32**
Generation and management knowledge. A view from the manager of packaging

Goran Dukic, Tihomir Opetuk, Tone Lerher **45**
An integrated model of storage and order-picking area layout design

Teresa Gajewska, Elżbieta Wyraz **56**
Flexibility of deliveries criteria connected with the competitiveness transport companies

Allen Greenwood, Travis Hill, Robbie Holt, Chase Saunders **65**
Using simulation to enhance procurement sourcing decisions

Jakub Jurasz, Jerzy Mikulik **74**
Scheduling operation of wind powered pumped-storage hydroelectricity

Krzysztof Jurczyk, Jerzy Mikulik, Katarzyna Gdowska, Wojciech Woźniak **84**
Demand forecasting with the usage of artificial neural networks on the example of a distribution enterprise

Waldemar Kaczmarczyk **94**
Does scheduling really have an impact on machine utilization in flow shop systems?

Maksymilian Kołodziej, Izabella Stach **101**
Control sharing analysis and simulation

Antoni Korcyl, Katarzyna Gdowska, Roger Książek **109**
A MILP model for route optimization problem in a municipal multi-landfill waste collection system

Jolanta Krystek, Sara Alszer **119**
The role of buffer warehouses in selected prodution systems

Małgorzata Kuźnar, Elżbieta Wyraz **128**
Analysis of the most elected interurban transportation modes among Cracow students of state universities

Tone Lerher, Vaska Pejic, Borut Jereb, Tomaž Kramberger, Bojan Rosi **136**
Lean and green logistics: a theoretical framework approach

Tone Lerher, Valerij Strmčnik, Iztok Potrč, Matjaž Šraml, Boris Jerman, Nenad Zrnić **144**
Simulation-based performance analysis of an order picking systemss

Augustyn Lorenc **156**
Method of effectiveness evaluation of products picking process for pick by order type in warehouse on basis of a picking list

Augustyn Lorenc, Maciej Szkoda **168**
Impact of a Just-in-Sequence system on the effectiveness of internal transport in automotive industry

Joanna R. Marszewska **178**
Implications of seismic hazard in Japan on Toyota's supply chain disruption risks

Daniel Muniz, Maria Fae **186**
Effects of transport logistics on local development in Serra, Brazil

Miroslav Musil, Vlastislav Laskovsky, Pavol Fialek **195**
Analysis of logistic processes using the software tecnomatix plant simulation

Ramon Baptista Narcizo , Alberto G. Canen, Iara Tammela **201**
Time-Based Competition: a case study in a Brazilian company operating in the oil and gas industry

Pavels Patlins, Remigijs Pocs **209**
Secondary and tertiary packaging improvement opportunities into logistics processes

Jacek Ryczyński, Paulina Krawczyszyn **216**
The use of AHP method to select optimum means of transport for strategic goods

Anna Rymaszewska, Petri Helo **221**
Creating customer value through the use of data

Goran Savic, Ljerka Luić **231**
Business intelligence in managing of technical-information system

Bartosz Sawik **239**
Multi-criteria mathematical programming approaches for assignment of services in hospital

Bartosz Sawik, Javier Faulin, Elena Pérez-Bernabeu, Adrian Serrano-Hernandez **247**
Bi-objective optimization models for green VRP approaches

Tadeusz Sawik **255**
Robust vs. resilient supply portfolio under disruption risks

Stefan Schmidt, Benjamin S.G. Schmidt **264**
New perspectives - digitalisation to advance production and logistics network

Lucía M. Schwarz I., Trina M. Schwarz I., María J. García G., Gilberto J. Hernández G., José G. Hernández R. **272**
Social impact of restrictions on inventory management

Zdenko Segetlija, Josip Mesarić, Davor Dujak **283**
E-logistics as prerequisite of e-retailing

Adrian Serrano-Hernandez, Javier Faulin, Mercedes Sanchez, Javier Belloso, Bartosz Sawik **292**
Locating a biorefinery under environmental criteria: a green facility location problem

Maria C. F. de Sinay, Gabriel A. De Araujo , Laura Sinay , Marta C. Dalbem **299**
Practices of corporate social responsilitity in large Brazilian industrial companies: an empirical study

Zilla Sinuany-Stern, Vered Kushnir-Berdugo, Doron Alper **308**
Factors effecting police station efficiency: DEA in police logistics

Dagmar Piotr Tomanek, Jürgen Schröder , Markus Wirz **315**
Value added heat map–a new method for the optimization of production space

Maja Trstenjak, Predrag Cosic **324**
Sequencing of single product operations with multiple technological criteria

Jiayi Wang, Jonathan Ebner, John Geraghty **332**
Characterization of multi-objective performance matrices in relation to inventory control strategies

Ewa Wankowicz **342**
Sustainable fibre for sustainable fashion supply chains: where the journey to sustainability begins

Mariusz Wasiak, Ilona Jacyna-Gołda, Mariusz Izdebski **352**
Multi-criteria warehouses location problem in the logistics network

Elżbieta Wyraz, Małgorzata Kuźniar **364**
Urban communication behavior among Cracow students of State Universities

Yuji Yano, Minoru Saito **371**
Making an efficient last mile delivery system in Japan

Arunas Burinskas, Aurelija Burinskiene **381**
A model of logistics services with heterogeneous firms

INDEX OF AUTHORS

Invited Speakers

PROF. ERWIN PESCH

RECENT ADAVANCES IN INTERMODAL TRANSPORT OPTIMIZATION

Short Bio:

Erwin Pesch holds a Chair in Management Information Sciences at the University of Siegen. He was employed as a Software Engineer at the Commerzbank AG and worked from 1989 to 2001 as an Assistant Professor at the Faculty of Economics and Business Administration of the University in Maastricht and as a Professor at the Institute of Economics of the University in Bonn. He holds a Ph.D. in Mathematics and a Habilitation in Business Administration both from the Technical University Darmstadt. His research areas are in Logistics, Management Information and Decision Support Systems, Project Management and Scheduling many of which are closely related to various industrial projects. He is author or co-author of 5 books and has published more than 170 papers in many international journals, among others in Mathematical Programming, Artificial Intelligence, Management Science, Journal of Combinatorial Theory, Journal of Graph Theory, IEEE Transactions on Robotics and Automation, Discrete Mathematics, Discrete Applied Mathematics, Naval Research Logistics, and serves on the editorial boards of 13 international journals including INFORMS Journal on Computing, Journal of Scheduling, Omega, Annals of OR, European Journal of Operational Research, Operations Research Letters. He organized the EURO conference with 2500 delegates in Bonn in 2009. He received many Federal Grants from the German National Science Foundation (DFG) and for more than 10 years always achieved leading positions in citation analysis and publication based rankings in German speaking countries. In 2008 he got the Award of the Polish Minister for Research and Education and obtained the prestigious Copernicus Award (with J. Blazewicz) in 2012.

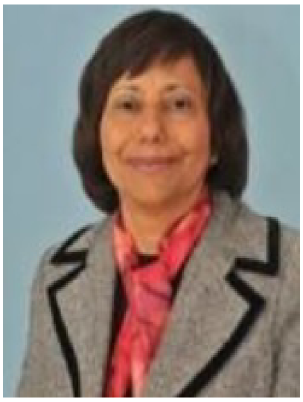
Abstract:

Attracting a higher share of freight traffic on rail requires freight handling in railway yards that is more efficient, and which includes technical innovations as well as the development of suitable optimization approaches and decision-support systems. In this talk we will review some planning and scheduling problems of container processing in railway yards, and analyze basic decision problems and solution approaches for the two most important yard types: conventional rail-road and modern rail-rail transshipment yards. We introduce new matching problems that generalize container assignment in railway yards and sea ports. Furthermore, we review some of the relevant literature and identify open research challenges. Additionally we address a scheduling problem that arises in intermodal container transportation, where containers need to be transported between shipper or receiver customers and container terminals (rail or maritime) and vice versa. The solution method can be applied to other problems as well.

PROF. ZILLA SINUANY-STERN

FACTORS EFFECTING POLICE STATION EFFICIENCY: DEA IN POLICE LOGISTICS

Short Bio:



Professor Zilla Sinuany-Stern is from the Department of Industrial Engineering and Management (IEM) at Ben-Gurion University of the Negev, Beer-Sheva, Israel (since 1978). She holds the Chair of Sir John and Lady Cohen Business and Industrial Management.

She earned a Ph.D. degree in Operations Research (OR) from Case Western Reserve University, in Cleveland, Ohio, USA, and BA and Master Degrees in Economics and Statistics from Tel Aviv University. She was the head of the IEM department in 1992–1994, and she was the Rector of Ariel University during 2000–2008. She was a visiting Professor in several universities in USA, Austria Australia, and Argentina. She was Vice president of EURO 2000–2004, and President of the OR Society of Israel (ORSIS) 1996–2000, also VP of ORSIS 1992-1996. She was Guest Editor of EJOR and Annals of OR. Since 1993 she is a member of the international advisory board of the Journal of Operational Research Society (JORS). In 2010 she won the ORSIS Prize for excellent paper (with D. Alper).

Her Areas of research are**:** Management Science – Operations Research, more specifically**:** Resource allocation, Efficiency analysis (DEA), Logistics, Decision Analyses, AHP, Multi Objective Optimization, Production Planning, Reliability and Maintenance.

She authored and co-authored over 150 publications, of which 100 papers are in refereed journals such as: EJOR, MANAG SCI, IIE TRANS, Annals of OR, JORS, CJOR, OR, INT J. of PROD RES, INT J. of Logistic SYS MANAG, J. of Transport GEOG, PROD PLAN Control, COMP & OR, COMP & IE, Location SCI, Accident ANAL PREV, Water RESOUR RES, R&D MANAG, COMP ENVIRON URBAN, J Regional SCI, Simulation.

She consulted for various organizations in industry and the public sector in the USA and Israel mainly in planning and logistics such as: Cleveland Trust Bank, Indiana Commission of Higher Education, Israel's Police Headquarter, Electric Authorities of the State of Israel, Nuclear Commission of Israel. Since 2012 she is a member of the Council for Higher Education in Israel, she also chairs the Committee of Quality Assurance there.

Abstract:

First the state of the art of Data Envelopment Analysis (DEA) in police and logistics is presented. Second an example of specific study is given. The purpose of the study is to identify regional and urban factors effecting police station efficiency in Israel. At the first stage, DEA is used to measure the efficiency of 60 police stations, based on 2 inputs and 16 outputs, including some logistic parameters. At the second stage, multiple-regression is performed to verify the effect of various regional and urban factors on the efficiency. Two factors were found significant: number of vehicles belonging to the population in the jurisdiction area of the station, and the southern region.

PROF. WALDEMAR KACZMARCZYK

DOES SCHEDULING REALLY HAVE AN IMPACT ON MACHINE UTILISATION IN FLOW SHOP SYSTEMS?

Short Bio:

Waldemar Kaczmarczyk is employed in the Department of Operations Research and Information Technology at the AGH University of Science and Technology in Krakow, Poland.

He holds a Master's degree in Operation Research from RWTH Aachen University, Ph.D. and a Habilitation in Automatics and Robotics from the AGH University. His research areas are in Operational Research, Production Planning and Scheduling and Supply Chain Management.

He is author of a book on production lot sizing and scheduling and has published more than 30 papers in international journals, among others in International Journal of Production Research and Decision Making in Manufacturing and Services. He was a key investigator in several grants of the National Research Committee in Poland and Motorola Advanced Technology Centre in USA.

Abstract:

The machine utilisation remains one of the most important objectives of the production planning and scheduling. Although utilisation is a characteristics of a long term stochastic process and the makespan describes only a single deterministic schedule, in production scheduling models maximization of utilisation is usually approximated by makespan minimization. Presented analysis of typical production planning system and experimental results show that in permutation flow shop systems with unlimited buffers the impact of makespan minimization on long-term machine utilisation might be significantly overestimated. To bridge this gap between theory and practice a new measure of quality considering multiple schedules is proposed.

PROF. ALAIN HAURIE

THE LOGISTICS OF SUSTAINABLE REGIONAL ENERGY SYSTEMS

Short bio:

Alain Haurie has been professor of Quantitative Methods at the Graduate Business School of the University of Montreal, Canada (1963-89). From 1989 to 2005 he was professor of Operations Research in the department of management studies (HEC) of the University of Geneva, Switzerland. During his academic career he has occupied positions of department chairman (1974-1976 in Montreal, 1989-1992 in Geneva) and has been the founder and first director of a research center dedicated to decision analysis (GERAD in Montreal 1980-1989), which became one of the leading research center in Canada for Operations Research. With Jean-Philippe Vial he has created in 1990, LOGILAB, a research laboratory that fostered Operations Research and Decision Science modeling in the domain of logistics and energy/environment.

He has authored or co-authored over 200 scientific papers and co-authored 9 books. He has been in charge of orienting continuing education programs at the university of Geneva (1996–2001). During various academic leaves he has also taught at Ecole Polytechnique de Montréal (1970-74), INSEAD, Rabat, Morocco (1976–1978), University of California, Berkeley, USA (1980), Victoria University, Wellington, New-Zealand (1993), Ecole des Mines de Nantes, France (1993–1995).

At University of Geneva he has taught Operations Research, Decision Science, Energy and Environmental Management in various undergraduate and graduate programs. He was also the director of a continuing education program on “environmental management for the firms”. He has directed several research projects dealing with the economics of energy and environmental management. From 2000 to 2005 is has been the director a large project of the Swiss Virtual Campus program to implement a distance learning modular course on sustainable development. Over the same period he has been the leader of a research group (nccr-“climate”) funded by the Swiss NSF to work on the economics of climate change.

In 1985 he has participated in the creation of HALOA inc., a consultancy firm based in Montreal, which specialized in the modeling and analysis of the interactions between energy and the environment. In 2002 he has participated in the creation of ORDECSYS a consultancy firm based in Geneva, Switzerland. He is currently CEO of ORDECSYS. The company has been active in several large scale projects funded by EU FP-6 and FP-7 research frameworks, related to the economics of climate change and energy transition. The company has also participated in projects supported by the Swiss energy board, the French research program on the impacts of climate change (GICC) and the Qatar national research fund.

ICIL 2016

International Conference on Industrial Logistics
Zakopane, Sep. 28 – Oct.1, 2016

Conference Papers

MODELING OF INDUSTRIAL LOGISTICS FUNCTIONS FOR ORDER HANDLED MANUFACTURING COMPANIES

Tautvydas BARGELIS[1], Algirdas BARGELIS[2]

[1]UAB ID Forty Six, Donelaičio 33-503, Kaunas,
Lithuania
[2]Kaunas University of Technology, Faculty of Mechanical Engineering and Design
Studentų 56, Kaunas,
Lithuania

Abstract:

The paper deals with virtual modeling of industrial logistic functions for order-handled manufacturing and information technology companies. At the future these companies will run on smarter software and hardware. The digitalization in various industrial and service fields especially in innovative products development and manufacturing is used in this paper. The wide integration of industrial logistics, product design and production functions by created model and searching optimal outsourcing schemes in accordance to work productivity indices is examined. Low cost and better efficiency of a product and process development is available to check and apply for each product's variant by modeling procedure.

Keywords:

industrial logistics functions, modeling, optimization, order handled manufacturing company

1. INTRODUCTION

Order-handled manufacturing system (OHMS) involves ordering production operations and customertailored end products in the form of making functions in accordance their mission. It is a "pull type" manufacturing that means make to order in which the production is based on actual demand. Research and practical experience [1,2] shows that production planning and control procedures can be more difficult to carry out when jobs are produced to order rather than for stock, because the operations are complicated by inherent sources of uncertainty. The objective of an OHMS may be divided into two types: 1) as the manufacture and delivery of real products, goods or components related with proper design and quantity to customers' specification and an appropriate guarantee of a product quality and prompt delivery at an acceptable cost, and 2) as the creation of a mental product or service (product and process specification, IT product or system and so on) with analogues conditions and requirements on the theretofore point. There are some various combinations [2] from conditionally mere work case to the more complicated work case including product and process development and its realization. The OHMS mostly is in unitary or batch production and very seldom in mass production. It is common in various nations but often it dominates in developing countries. Industrial logistic functions play a major role in the computerized highly automated industry of today. Automating of manufacturing processes in company will affect logistics issues concerning input delivery as well as distribution of information. Developing a new innovative product, process or software require a significant factor of concurrent engineering job and methods [3] including industrial logistics functions (procurement, storage raw materials and components, final products, work in process, intra-plant transportation and so on). These aspects lead to cross-discipline systematic approach to the integrated, concurrent design of products and their related processes from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements [4]. Cross-discipline approach can combine aspects of many engineering specializations as mechanics, electrical, mechatronics, informatics, manufacturing science, logistics, etc. This approach is a background of computer integrated manufacturing (CIM) system development and exploitation. CIM systems lead company to higher automation level exchanging hand work of humans by software and hardware and applying interfaces starting from control of different machines and tools to manage production divisions and companies.

The future tendency of industrial production is related with globalization, innovation and technology transfer. Innovation is advantage method for company survive in global competition [5]. Globalization offering many possibilities choosing bigger alternatives of operating conditions because knowledge and experience in companies lead to new challenging developments. Operators in developing countries are striving to challenge the achievements of global manufacturing leaders sharing worldwide market by low production cost and reliability. It is available by sustainable development of products and processes due to the green energy resources, saving raw materials and searching methods of decrease their consumption to get advantages before competitors. New technologies have changed industrial fields by cross-disciplines as mechatronics and wide application of information and communication means; such technologies create many chances to develop new innovative applications and new generation produts and processes. All abovementioned expedients enhance productivity and efficiency, while creating the preconditions for new innovations. Many factors have influence to the company size; it is going to be smaller signifying that large companies are inherently difficult to design, co-ordinate and maintain. On the other hand not always manufacturing cost is least and production is more efficient in large company. There are some research studies related the company size [5]; not always the large company has its advantage versus small ones. It is important to know that automation procedure is more complicated in small enterprise and to integrate the industrial logistics functions in production process. The quality problems are related very close with work productivity and problems finding the new orders exists because the biggest part of orders consists of products and components that are developed by customers [6,7]. It is concerned with insufficient cooperation with customers, and lack of specialized quality tools and methods.

Industrial logistics functions work as links or interfaces among subsystems in cross-discipline system. In 21st century all available systems have very complicated structure and mission. Therefore, industrial logistics functions are particular and very different and must be able to support actions of every subsystem creating wealth of overall system.

Lithuania is a country of producers when many small and medium enterprises (SME) produce various products, their parts and components according to the orders of customers. In biggest part of orders, unfortunately, the product development and design is made by customers and many quality and productivity problems appear to producers. It is due to high variety of customers, their work traditions and very small production volumes. The consideration of Lithuanian SMEs production results has shown certain quality and low manufacturing cost problems when companies' stakeholders exploiting modern CNC facilities often have product and process quality failures. These failures deal with both the product and process design questions, and order quotation inaccuracies when producers have been very optimistic. No quality prevention and only minor quality appraisal cost in considered small-scale Lithuanian SMEs has been fixed in this research. This paper has two purposes: (i) to establish a linkage between some aspects of manufacturing operations and industrial logistics functions, (ii) to create and exam model of interfacing industrial logistics functions between manufacturing engineering and new product design. It is a hope that results of this study will allow senior management and engineering team to better understand these inherent relationships. For researchers in academia and industry, this study may provide a stepping stone toward examining the impact of this consistency of relationships between industrial logistics functions and manufacturing functional strategies, such as product and process design, marketing policy or R&D strategy on organizational performance.

2. INTERACTION OF INDUSTRIAL LOGISTICS AND ENGINEERING FUNCTIONS

It is a frequent question in medium of industrialists and academia manufacturing scientists how Industrial Logistics deal with a particularly challenging issue, which has yet to become actual position, i.e. how industrial logistics play an important role in the computerized highly automated industry of today. Process automate will affect logistic issues concerning input delivery as well as distribution, i.e. the two sides of the interfacing chains. Developing a new innovative object can be sped up a significant factor if concurrent engineering methods (CE) are used including industrial logistic considerations [8]. CE is not alone engineering method helping finding the innovative solutions because during last two decades are widely applied the couple of new methodologies as Design for Parameter X (DFX) that have created platform of an integrated approach for the development a new innovative object [9]. The new idea in this research is application of the parallel interaction the industrial logistics and engineering functions for advanced development the technical complicated systems. The action of industrial logistics in complicated system among two real and mental sides of input-output can be expressed as numerous links. The objective of mentioned link is finding interaction decision and appropriate realization means in whole system. The specific case of input-output links is creation the innovative system; it can be principally new system or redesign of an old system that shows better utilization and competitiveness indices in market. The interaction links may be created for every pair of conterminous member both real and mental OHMS. Table 1 shows the structure of the interaction links among the conterminous member of every pair the real technical system type.

These links should make the parameters and objectives of every conterminous pair of a created system. The parameters and objectives of links are defined by two types of attributes – *attribute out* and *attribute in*. *Attribute out* means the member that is superior of a developed system pair and its parameters influence to the structure of an *attribute in*; the structure and volumes of latter attribute determines the benefit factors and quality of solution the any considered pair. Such actions may be carried out for all available pairs of a created technical system. The effect cost of industrial logistic to every interaction link of *attribute out* / *attribute in* (Table 1) is defined in accordance of the planned tasks, operations types and quantity. Latter costs can upgrade the benefit factors and decrease the operation cost [9]. It is an art of a value engineering the product and process development including industrial logistics functions seeking best benefit's factors by optimal sharing parameters among industrial logistics and engineering functions. The aim of value *engineering* is interfacing the product design and process development together with industrial logistics functions seeking the value index increase applying the following dependence: *Value = Product performance / Product cost*.

Table 1 – The interaction links among of conterminous member every pair of a real product

Attribute out	Characteristics and properties	Attribute in	Benefit factors
Product	Type, size, mass, dimensions, quantity	Process structure	Production time, cost, quality
Mold	Mass, volume, dimensions	Machining, assembling, and testing	Production cost, quality, productivity
Die	Mass, volume, dimensions	Machining, assembling and testing	Production cost, quality, productivity
Sheet metal design	Type, size, volume, quantity, dimensions	Stamping, cutting, welding, painting	Production cost, quality, productivity
Furniture	Type, size, volume, quantity, dimensions	Wood machining, assembling	Production cost, worth,quality, productivity
Electronics	Type, size, volume, quantity, dimensions	Soldering, mounting, assembling	Production cost, quality, productivity, worth
Machine tool	Type, size, volume, quantity, dimensions	Machining and assembling	Production cost, quality, productivity, worth
Refrigerator	Type, size, volume, power, dimensions	Stamping, plastics operations, assembling	Production cost, quality, productivity, worth

The interfacing methodology shows how every exchange of product structure element as design features, parts, components and materials upgrade product performance (Figure 1). On the other hand, for every product upgraded version of performance the cost is checked. The best value has a product and process variant which biggest their value index is achieved. The minimum number of conterminous pairs in every technical system fluctuates from 1 to 10 and even more. It depends on the technical system complexity and purpose. The cross-disciplinary research of interfacing among industrial logistics and engineering functions and appropriate knowledge have been used. Mechanical engineering, electronics, manufacturing operations, qualitative and quantitative parameters, information technologies also computer aided design (CAD), computer aided process planning (CAPP), enterprise resources planning (ERP), flexible machine stations (FMS) and other computational and manufacturing methods have been applied for this research. The products and their components, parts and design features classification methods widely have been used in this paper. The appropriate classifiers have been developed and used [10]. They helped for products and processes design, definition of manufacturing cost and creation of industrial logistics interfaces and *attributes out* and *attributes in*. The developed methodology matches for any product design and process development. It is applied and validated in Lithuanian industrial sector, particularly presented in Table 1.

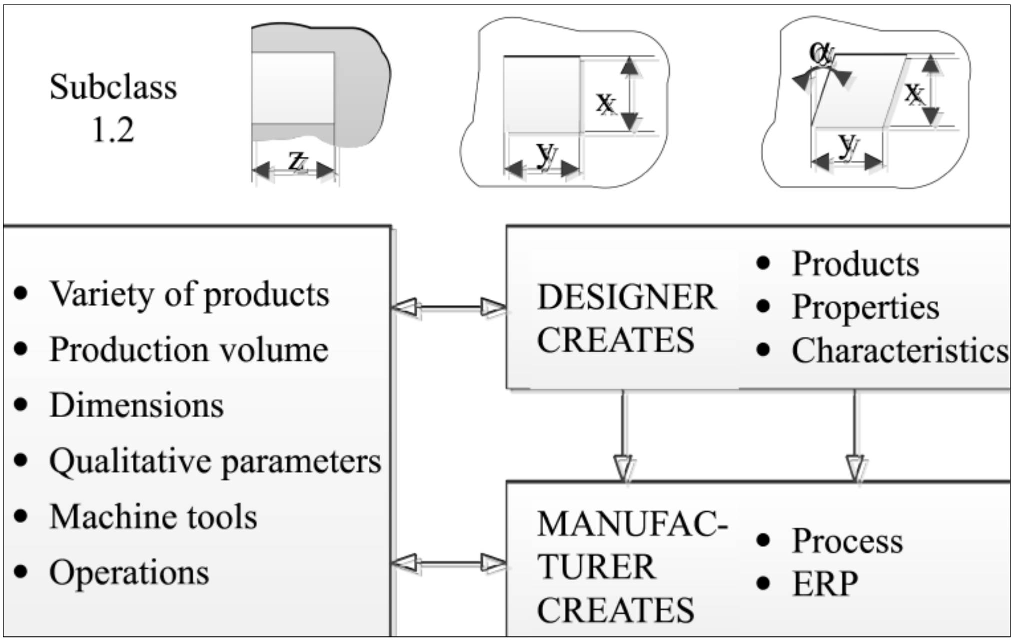


Figure 1 – Different view of designer and manufacturer work through industrial logistics focus

Table 2 shows the structure of the interaction links among the conterminous member of every pair the mental system type. The characteristics and properties of an *Attribute out* shows systems type, architecture, purpose, and data exchange possibility and speed as well as *Attribute in* shows input data, operations planning, system resources planning, relationship data and pattern behaviour. The links of mental system type are oriented to develop the interfaces among various systems and sub-systems decreasing the number of input data. This way is leading to the automate work level of a mental system; unfortunately, it is not always available to achieve this level checking the technical-economic indices because expensiveness of development. In this case the man-machine systems are created. The CAPP, Expert system and CRM are mental systems based on man-machine structure. The brain based knowledge to engineer is left and rest functions are divided to computer. CAPP system [10] successfully is used in Lithuanian industry more than twenty years. The mechanical part machining operations and their sequence and machine tools are defined by engineer. Work piece operation and material consumption, machining and manufacturing time are carried-out by software program of CAPP system. This work is available to carry out by outsourcing partners together withproduction of specific parts or components. This is possible when potential partners have effective machine tools and tooling and are able to produce cheaper with required quality. Such data is included in the DB of every company manager and engineer; on the other hand, interfacing among managers, developers and technologists often help to find new ideas for innovative solutions in product or component design changing the geometric view of whole product, some materials and even structure aiming easier manufacturing.

Table 2 – The interaction links among of conterminous member every pair of a mental product

Attribute out	Characteristics and properties	Attribute in	Benefit factors
System	Type, architecture, purpose,data exchange possibility	Input data and type	Procedure time, cost, reliability
CAPP	Man-machine systems	Operation planning	Procedure time, reliability, process plan
ERP	Mass, volume, dimensions	System resources planning	Production cost, quality, productivity
PDM	Type, purpose, worth	Sheet metal design system CNC operations	Procedure time and cost, reliability
Expert system	Type, purpose, worth	Process operations planning	Procedure time and cost, reliability
CRM	Procedure time and cost, reliability	Relationship data, behavior of pattern	Procedure time, cost,productivity, worth

3. PRODUCTIVITY, WORTH MODELING OF INDUSTRIAL LOGISTICS AND ENGINEERING FUNCTIONS

Modeling of industrial logistics and engineering functions seeking product quality and functionality with lower cost, when product is designed and manufactured according to order of customer is applied in this research. Theoretical and experimental methods of examination based on acquisition, systematization, classification and managing of engineering and logistics knowledge as well as experimental planning are used. Data of these methods have been gained from experiments and created theoretical knowledge applying parametrical functions. Parametrical dependences evaluating the influence of product design characteristics and properties on industrial logistics and manufacturing process structure as well as cost have been created. These dependences were approved experimentally estimating an interaction error value. Experimental research was performed directly studying and researching manufacturing processes and industrial logistics as well as their interfacing, chiefly creating common industrial-engineering systems [11].

Figure 2 shows interfacing model block of industrial logistics and engineering functions that matches to design for logistics (DFL) approach. It consists of three engineering members as product design, process design and manufacturing. They are connected with each other by logistics links. These links have two way directions that permit do reaction into conterminous member and do reaction back after its impact. Such actions are repeated till desirable result will be achieved. Product design member of a model creates product or system alternatives and searches best alternative after interaction with process design member of a model. As it is available to see from Figure 2 main design tool is 3D CAD software with application of standard components. Process design member of model develops work piece, process plan and operations, searches machine tools and tooling, does setting of manufacturing resources and definition of ERP for every process alternative. Every process alternative is analyzed looking other possibilities to decrease the manufacturing resources applying industrial links with product design characteristics and properties.

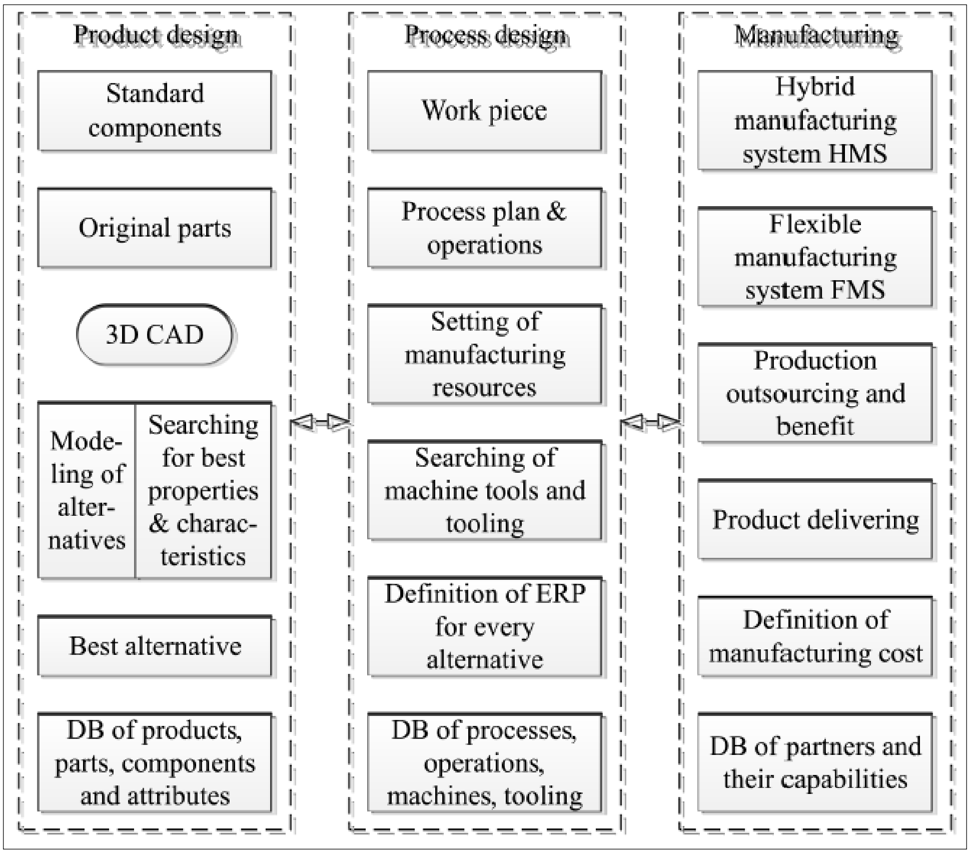


Figure 2 – Interfacing model of industrial logistics and engineering functions

Last stage is manufacturing of developed product and applying innovative processes as discussed above. There are two types of manufacturing systems: 1) Hybrid manufacturing systems (HMS) and 2) Flexible manufacturing systems (FMS). The HMS is common in many countries and widely is still used during past two decades. It is combined manufacturing system that apply human work and programing machine tools with high qualified operators. Operators are responsible for loading machine tools by work pieces and NC control programs. HMS matches to OHMS because the unitary products of high variety. The FMS is more automate comparing with HMS and belongs to advanced manufacturing system. First step of FMS implementation is development of a virtual model and its verification for company needs. The FMS modelling is used for increase the work efficiency in industry and vocational employees training. It is based on the re-arrange of traditional human resources planning at the HMS and jobs combining interacting among robotics and hand-held work. It is emphasized with the CNC machines loading and unloading operations by work pieces in the whole FMS at the order handled manufacturing. As in the current FMS strategy the target to achieve a total automate work of every FMS operation seeking to remove hand work have many troubles and problems because complicated robotics and low loading time and have not betrayed the hope of efficiency. This is a main reason of very expensive machining work and long term of operations in FMS. The developed FMS virtual simulation model is based on a man-computer system and is presented in Figure 3. Its inputs as component mass and material, characteristics, design features (DF) and dimensions, machine-tool, mass of the work piece, and production volume have been used. The outputs of a developed virtual simulation model as simulation of the machining process, component machining and floor to floor time have been defined. The concurrent and parallel processing on product and process design is concentrated in DFL.

In order to get an efficient process of mechanical product design with permanent improvement, more alternatives must be created and tested in the shortest possible way. While carrying out research, creating and developing previous models and generating mechanical products and their components, possible changes of parts, procurements, customers' requirements as well as the manufacturing and technical environment conditions have been taken into consideration. Due to the modern manufacturing environment, the aim was to compose an integrated manufacturing model which would enable to uninterrupted whole creativity process. Industrial logistics functions have a major impact to the *user-developer-supplier-manufacturerseller* chain. The role of a latter chain is to facilitate the real time of a search products' ideas, new markets, time planning, the concept of innovative product and process. Taking into account the integrated environment of industrial logistics and engineering functions the virtual model it is an easier to estimate gotten customers' requirements and implement new ones with higher level of a creativity, novelty and innovation. Going to keep the requirements of an international competiveness every developer and manufacturer has to look the new findings and developments slightly implementing the mass production methods in unitary production system. The FMS methodology matches for this very well with creation of a new tooling and storing technique. The industrial logistics methodology in particular outsourcing ways finding new overseas companies and organizations including material and components suppliers was used.

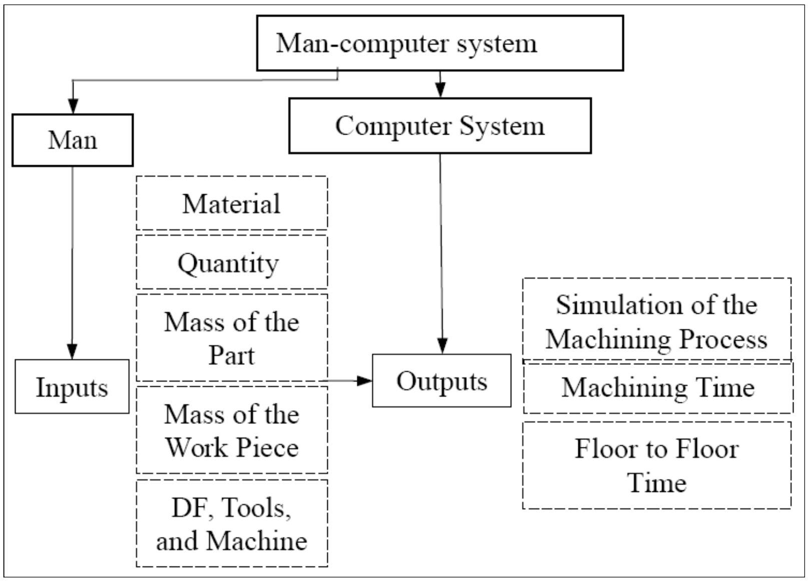


Figure 3 – Scheme of the FMS virtual simulation model and its functions

4. CASE STUDY

There is taken a typical medium manufacturing company that develops, designs and produces dies for stamping parts and components of the cars from thin sheet metal (Table 3). The dies are classified into three groups by complexity: progressive, compound and individual [9]. It is a joint stock medium company of Germany (80% of shears) and Lithuania (20% of shears) that is located in Kaunas, Lithuania and produces mentioned three groups of dies. A typical mechanical component – a holder with three types of design features and their qualitative – quantitative parameters has been taken. Firstly, a 3D CAD model of a chosen component has been created using the standard SolidWorks CAD software. Next step is showing a sequence of interaction links among the conterminous of every pair according to the description of Table 1. Considered die has three *attributes out* as die type, die production volume of component and total number and its variety of component DF. Die type is defined as progressive because big production volume of component, and high number of component DF. There are also three *attributes in* as machining, assembling and testing operations. The interaction among *attributes out* and *attributes in* define the die production cost, quality and work productivity; interfacing action among attributes to die parameters is showed below.

Table 3 – Die of a sheet metal design components production

Die type	Dimensions of die, mm	Dimensions of component, mm	Number of die parts and DF	Total number of component DF	Component stamping volume
Progressive die	950x200x125	65 x 40 x 1.5	26 parts, and 45 DF	5	200 000 components / year
Compound die	260x260x125	40 x 40 x 1.2	12 parts and 18 DF	6	40 000 components / year

Third step shows a sequence of interfacing model among industrial logistics and engineering functions aiming at the optimal alternative of the process plan in the conception stage of a die development in accordance of Figure 2. During die design stage many logistics links have been discussed among car sheet design component developer and die designer. There were searched as more as possible to apply standards components in die design and decreasing the number of original parts. Best alternative of a progressive die with components, specification and parameters have been placed in DB of products. Parallel the modeling of die alternatives with best properties and characteristics have been searched applying the industrial logistics functions for process design. The optimal variant of work pieces to all original die parts and components have been created applying links of industrial logistics and combining various machining possibilities and operations. Process plan and operations for all die parts together with setting of manufacturing resources and machine tools and tooling have been made. Last stage of process plan development is definition of ERP for every die alternative and estimate best variant that is placed in DB of processes, operations, machines and tooling.

Forth step is divided to manufacturing process realization in company applying HMS or FMS systems. It depends what system is developed and used in company. The wide industrial logistics links and functions for production are employed including separate operations, components and parts. Wide net of outsourcing companies inside of all Europe Union and regional countries is applied. The optimal indices as distance among companies, possibilities for quality, cost and reliability of cooperation are destined. The considered company own trucks and other transport means are used for transportation made production saving the cost.

The next compound die (Table 3) has been also considered in this research practicing analogous above mentioned consecution. The die development and production time of compound die and cost have been defined applying known methodology [9]: die development time is 115,82 h and cost is 1174,0 Eur, die production time is 215,0 h, and cost is 1 868,0 Eur, and materials cost is 1000,0 Eur. Development and production time and cost was minimized due to the help of a created interaction model among industrial logistics and engineering functions aiming of optimal structure both the product and process.

Another company considered in this research work is a small IT enterprise developing and exploiting ERP software divided to various small and medium manufacturing companies. The main functions of a software are as follows: finding suppliers of cheapest materials and work pieces, finding partners for common work of orders and customers, definition of orders cost, sending developed DB of potential customers in regionals and whole Lithuania, development of customers and suppliers net, searching logistics partners for delivery.

5. CONCLUSIONS

The research in this paper presents a functional model for the interaction among industrial logistics and engineering functions in the hybrid manufacturing system for the integrated product and process design. The industrial logistics and their links work as interface between product and process development. The DFL approach as a functional model based on the integration of information flow of separate domains applying the knowledge base and combination of industrial logistics and engineering methods for the product and design method has been developed. It has been stated that the optimization process is a time consuming and a

consecutive scheme has been used for the manufacturing process creation. The method that has been described in this paper accomplishes the purposes of this research. However, this is not the only method currently available. It has its advantages and disadvantages. The advantages are several: a linkage between some aspects of manufacturing process and operations and industrial logistics functions have been established, and model of interfacing the industrial logistics functions among manufacturing engineering have been created and considered. The principal shortcoming of the developed model is a poor intelligence and big volume of hand job in interfacing of different jobs. Briefly it is concluded as follows:

- 1. The functional model by using the object-oriented approach that describes the properties of different industrial logistics and engineering functions and relations among them has been created and considered.
- 2. The developed data base of a model encompasses the information about products, processes and manufacturing resources and production resources; it is applicable to the optimal process planning.
- 3. The created DFL approach helps to disclose the regularity of changes of the manufacturing cost by changing the structure of the product and process: the combination of operations and allowances diminish the cost of materials and other resources.

6. REFERENCES

[1] Shewchuk, J.P., Moodie C.L.*: Definition and classification of manufacturing flexibility types and measures*, International Journal of Flexible Manufacturing Systems, 24(4)(1998), 325–349.

[2] Berlec, T., Starbek M.: *Forecasting of production order lead time in Sme's, Iranian Journal of Science & Technology*, Transaction B: Engineering, 34(B5)(2010), 521–538.

[3] Barros, L., et al.: *Logistics in the Information Society*, Proceedings of International Conference on Industrial Logistics, 2003 Vaasa, Finland, June 2003, 16–19.

[4] Hundal, M.S.: *Systematic Mechanical Designing: A Cost and Management Perspective*, ASME Press, New York, 1997.

[5] *Editorial report, a third industrial revolution*, The Economist, 2012, April, 1–3, http://www.economist.com/node/21552901, 2016-04-12.

[6] Setijono, D., Dahlgaard J.J.: *The value of quality improvements*, International Journal of Quality & Reliability Management, 25(3)(2008), 292–312.

[7] Bargelis, A.: *Web-based integration for knowledge sharing in hybrid manufacturing system*, Proceedings of 10th Commemorative International Conference on Productivity and Quality Research ICPQR [electronical source], 2004, Miami, Florida, U.S., February, 12–15.

[8] Prasad, B.: *Concurrent Engineering Fundamentals – Integrated Product and Process Organization*, Prentice Hall PTR, New Jersey, 1996.

[9] Boothroyd, G., et al.: *Product Design for Manufacture and Assembly*, Marcel Dekker, Inc., New York, 2002.

[10] Mankute, R., Bargelis, A.: *Innovative process development applying intelligent computer aided process planning system*, Proceedings of International Conference on Industrial Logistics, 2010, Rio de Janeiro, Brazil, March 08-11.

[11] Bargelis, A., et al.: *Collaborative-Based Framework for Business Workflows Development and Management on the Web Site*, Abstracts of Presentation the International Conference of Manufacturing Technologies and Manufacturing Growth, 2012, San Diego, CA, USA, October 30 – November 2.

SECURITY & SAFETY (S&S) AND THE LOGISTICS BUSINESS

Esther A. BARRETO O.[1], Gilberto J. HERNÁNDEZ G.[1], María J. GARCÍA G.[1], José G. HERNÁNDEZ R.[1]

[1]Minimax Consultores, C. A.
Urbanización El Bosque Chacaito, Caracas
Venezuela

Abstract:

Two aspects that attract attention of the organizations are the safety and the security (S&S). Since the logistics business is related to almost all areas of the organization, it can think of making use of the same to analyze the S&S. An approach used to study the logistics is the Logistic Model Based on Positions (LoMoBaP [MoLoBaC]), that studies the logistics through functions. All of the foregoing arise the objective of this work: Show as through the Logistic Model Based on Positions it is possible to do an exhaustive analysis of the safety and security in an organization.

Keywords:

Safety, Security, Business Logistics, Logistic models, MoLoBaC, Internal relations

1. INTRODUCTION

In Spanish language safety and security are expressed with the same word “Seguridad”. But it is not only in Spanish where these two terms are confusing, in English and in the specialized literature are also presented different interpretations. To provide a little more clarity on both terms, says Mattson [1], that security is referred to situations that threaten the organization, as well as the lives of its members and is associated with intentional facts (malicious facts), while safety, is also associated with damage to the organizations and that particularly affecting humans, but are accidents that are not caused intentionally. On the other hand Rashid & Rashid [2], indicate that safety is a very important and mandatory function in any productive system. At the same time Hao, He & Zhang [3] refer the security as an industrial competition. Caputo, Pelagagge & Salini [4] indicate that the safety of the plant is one of the biggest concerns for industrial activities, because they can involve major economic losses and what is more important, human lives. And Magnusson [5] affirms that from the point of view of the organizations the security takes as a principal intention to protect the company and his assets of threats. These latter comments, put in relevance the importance that both the security as the safety have in the modern enterprise. As both security and safety (S&S) are focused on protecting the assets of an organization, being the most important of these human resources, safety and security (S&S) cover all areas of the organization.

Moreover, it has been commented on Hernández, García & Hernández [6,7] and in investigations quoted by them, that business logistics relates to almost all areas of an organization, having mentioned, to highlight just some: quality, costs, maintenance, expansion and growth of the organization, industrial design, works of compilation, classification and use of materials that return the organization, location and marketing and selling. Also García, Hernández & Hernández [8], analyze relations of business logistics with: human resources, production, quality, marketing and finance, but additionally they emphasize that this great interplay gives, logistics, a great advantage when it want to have a general understanding of organizations, but it is a disadvantage when it wants to explain to those who are just beginning in its study. And they note that this great dispersion of knowledge has forced that in the academy will create four models qualitative-quantitative to facilitate their study (Barreto [9]; García, Hernández & Hernández [8]; Guerrero et al. [10]; Hernández, García & Hernández [6,7]). Each of these models explain the logistics from a different point of view: the Supply, Production, Distribution and Inverse Logistic model (LSPDI, in Spanish el modelo Logístico, Abastecimiento, Producción, Distribución e Inversa [LAPDI]) focuses on logistics flows to analyze business logistics; the Logistic Model Based on Positions (LoMoBaP, in Spanish Modelo Logístico Basado en Cargos [MoLoBaC]) taking into account all the functions performed in positions related to business logistics; the Logistic Model Based on Indicators for Positions (LoMoBaIPo, in Spanish Modelo Logístico Basado en Indicadores de Cargos [MoLoBaICa]), it overlaps the MoLoBaC and analyzes the logistics through performance indicators and the Logistic, Strategic, Tactical, Operational with Inverse Logistics Model (STOILMo, in Spanish Modelo Logístico, Estratégico, Táctico, Operativo con logística Inversa [MoLETOI]), it is based on the three components of the administrative pyramid the: Strategic, Tactical and Operative and including reverse logistics, analyzes the business logistics. In this paper the interest will be centered on the MoLoBaC and it will be seen as the S&S can be studied thorough its positions, although to simplify the detail will do only at level of areas.

Than indicated in the preceding paragraph, the aim of this paper emerges: show as through the Logistic Model Based on Positions it is possible to do an exhaustive analysis of the safety and security in an organization. To achieve this general objective will include three specific objectives:

- Present the Logistic Model Based on Positions.
- To determine aspects that in the organizations could be associated with the S&S.
- To show how through, functions performed by different positions of MoLoBaC, it is possible to attend to the S&S.

With regard to limitations and scopes, there will be no field studies, but analysis between logistics and the S&S will be done through the functions of different positions of the MoLoBaC and it will be presented through a hypothetical view of a general nature, to give greater universality to the study.

1.1. Methodology

To achieve the general objective and specific objectives, it will make use of the Integrated-Adaptable Methodology for the development of Decision Support System (IAMDSS, in Spanish, Metodología Integradora-Adaptable para desarrollar Sistemas de Apoyo a las Decisiones [MIASAD]), which it was developed to create support systems, but for its flexibility adapts to different types of research (Barreto [9]; Guerrero et al. [10]). MIASAD, as it explained in García, Hernández & Hernández [11], facing the investigations without passing through the development of hypothesis, but a set of steps are followed, which can be adapted to each situation, particularly. For this work will be used: a) to define the problem that, as stated in the objective is show as through the MoLoBaC it is possible to do an exhaustive analysis of the S&S in an organization; b) develop a first prototype, which, among other things, users of the final product are recognized, in this case, because it is a scientific article, will be identify its main readers, that will be all those interested in S&S, those who will join students of business logistics, from all aspects, especially interested in analyzing the deep relationships that has the same with almost every aspect of organizations. Also it is necessary to establish the structure of the article, which in addition to this introduction will consist of three central chapters, in the first, will be presented MoLoBaC, in the second chapter, some aspects where is relevant the S&S in an organization will be presented and in the third chapter, which comes to be the principal one of the work, it will presented as it is possible to study the S&S of an organization paying attention to some of the functions that can redeem different positions of the MoLoBaC. The work will close with a chapter for conclusions and future investigations; c) search data, particularly on S&S and logistic models, especially the MoLoBaC; d) define alternatives, that consists of visualizing how it is possible to analyze the S&S using of functions performed by the positions of the MoLoBaC; e) evaluate alternatives, see the feasibility of having a clear vision of the S&S through the functions chosen; f) selecting the best alternative, according to the secondary objectives, tacit or explicit that have been contemplated; g) to implement the select alternative, that is to say to establish all the mechanisms that allow that the functions chosen to take a certain control of the S&S in an organization and h) establishes controls or mechanisms to recognize that the alternative chosen is still valid in time. It is important to emphasize here that an alternative rather than a function, it will be a set of functions.

1.2. The Logistic Model Based on Positions (LoMoBaP [MoLoBaC])

As already it mentioned can be found logistics business relationships with such diverse areas of organizations such as the environment through reverse logistics (Hernández, García & Hernández [6]; Pishvaee & Torabi [12]) and even through reverse logistics can be found relations with the location of the facilities of the company and retailers (Cardoso, Barbosa-Póvoa & Relvas, 2013 [13]) and it is possible to go further away and obtain a relation of the logistics with the social responsibility of the organizations, either directly or through the Supply Chain (SC) (Pishvaee, Razmi & Torabi [14]) and this to mention only a few of these relationships. These multiple relationships of logistics with the rest of the organization have been obliged to develop models for its study. Of these models the emphasis will be on the Logistic Model Based on Positions (MoLoBaC) (Hernández, García & Hernández [6,7]) which is shown in Figure 1, where it is possible to see that its structure obeys to a flow chart and that is integrated by forty four positions, identified each of them for a number.

The positions are grouped in areas and these at a time in stages, thus distinguishing the following stages: a) Supply, which consists of a single area, Procure, which is pure, while being formed by positions that belongs to a single stage, b) Production, consists of two areas, Maintenance and Inventory, both pure, c) Distribution, consists of four areas, Order processing, the first of the mixed areas, since it integrates positions of Production and Distribution stages, Physical distribution, another pure area, Transportation, the second mixed area composed by positions of the stages Distribution and of General of the company and the area that comes to be the reason of the being of the model, Costumer service, who also is pure, d) Inverse, formed an unique pure area, Inverse logistic, e) General to the company, consists of three areas, Intrinsic to logistics, Supported by logistic and Supporting logistics, all three pure areas and finally the stage f) Information (General of information), integrated by the last one of the mixed areas, Information, since it has positions of the stages General of information and General of the company.

Having presented the MoLoBaC, next a few brief comments of S&S will be made.

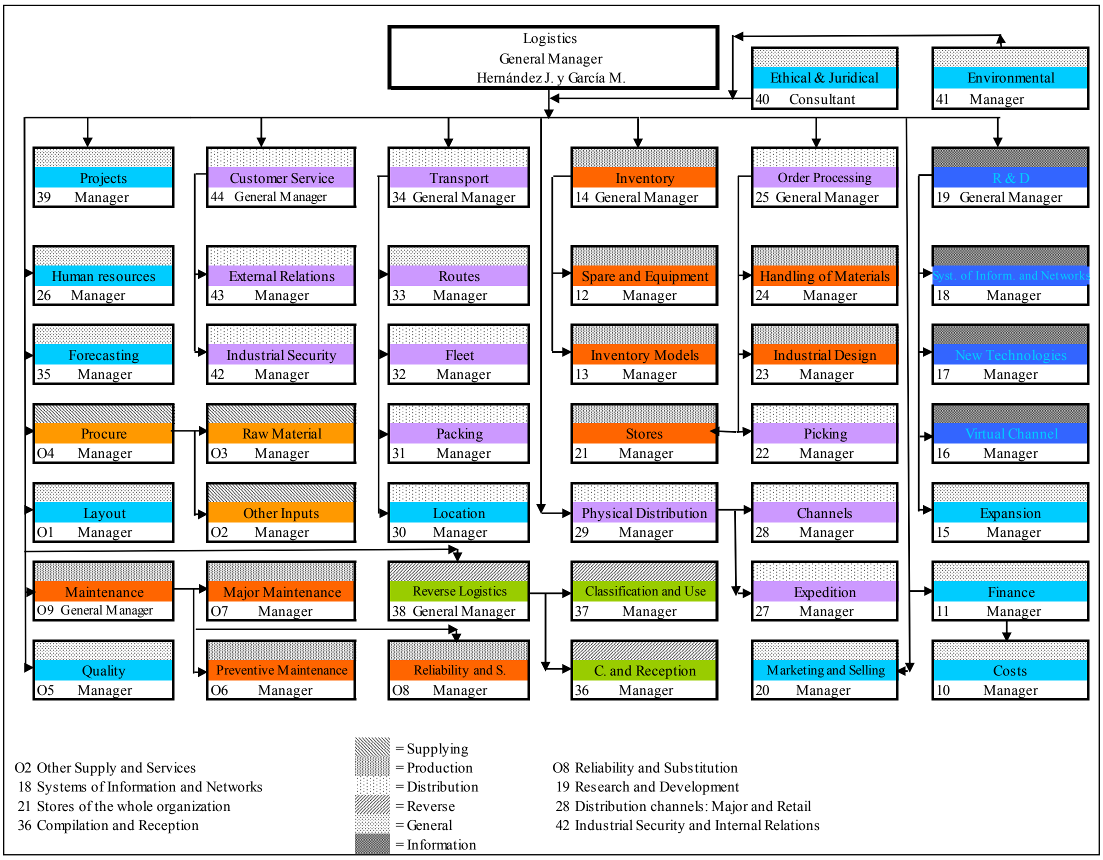


Figure 1 – Logistic Model Based on Positions (LoMoBaP [MoLoBaC])

2. THE SECURITY & SAFETY (S&S) IN THE ORGANIZATIONS

In last times one of the biggest concern of the organizations with respect to security they were the managerial secrets, that is to say, that the competition will not appropriate of what it was coming to be the Know-how of the organization (Winkler [15]). Although this is still a concern, today it is also provides a great interest to sabotage and terrorist attacks (Colwill [16]; Kabay [17]), by which the management of the information or security in handling information (Colwill [16]; Crowley [18]), it has practically become the first priority.

With respect to safety, although the organization is essential to make business life, the highest priority is focused on employees (Azadeh & Sheikhalishahi [19]; Khdair, Shamsudin & Subramanim [20]), for which the majority of preventive measurements, they are directed to protect to the personnel.

In this sense, for S&S it is necessary to pay attention to a big quantity of aspects, that for taking a starting point it could begin in the selection of the providers, which must offer the biggest possible S&S, not only in the supplies that will make come to the organization, but also in all matters relating to information management and aspects of the organization that are vital to their survival, as well as having warranty not encouraged to sabotage the organization or even to realizing attacks to the same one, making use of what could be called Trojan horses, that cause problems a posteriori. These attacks could be directed to the physical structures or to information systems. To continue in the order of the aspects to care, the organization must prevent any future risk, making a proper review of all inputs received and here, as has already been said and is to be understood in the rest of the work, these inputs can be either physical or virtual (relating to Information Systems). In the same order of idea must be followed with the utmost care in the internal management, not only of supplies, but of products in processes or finishes, including in this internal handling its storage. In all these aspects, attention must be paid to both the safety and security. Simultaneously must pay attention to customer orders, that in an extreme case, for disproportionate, could be an element of sabotage, it can also try those who assume the figure of clients to access the organization and to be able to make any terrorist attack on it. And following the route of the inputs, attention should be given, especially from the point of view of safety, to the entire production process, since it is during the same where usually to occur the greatest quantity of accidents. Here, a good design of the productive process, a suitable handling of the Picking and environmental measures can be of great help. Following the production chain, will come the dispatch of final products, where again it should prevent any deviation of the physical as well as virtual aspect and to analyze with a lot of care the distribution channels. Done the dispatch would come the transport of the products, where there can be another flank of attack to the organization and where many industrial accidents usually happen, especially when it is a question of the handling of products of high risk (Bernechea & Viger [21]). Here additional factors come into play as diverse as the packing, the location of the company facilities, fleet, routes to follow. Finally there would stay the handling of the products that must return to the organization, it is already for being packing or reusable parts or for returns of the clients. Now the processes of compilation, reception and classification turn into protagonists for the S&S. It could give details of these and other factors, but with what has been said so here, it has a fairly clear idea of all aspects that are likely to be affected by the lack of good policies S&S. Below it will pass review, as through a good handling logistics can minimize the impact of many of these factors influencing the S&S.

3. THE SECURITY & SAFETY (S&S) AND THE ENTERPRISE LOGISTICS

The need to ensure the security and safety (S&S), as it was commented in the previous section, it is in practical sense an obligation of the whole organization. As the Logistic Model Based on Positions (MoLoBaC) also, practically, covers the whole organization, with its forty four positions, some of the functions to be performed their different positions are analyzed to ensure good S&S. To simplify the presentation will be done through table 1, where each of the functions cover one or more aspects of S&S. Since it is forty-four positions and that some functions could be shared by several of them, table 1, will be organized by areas of MoLoBaC, however at the end of each function a number or several numbers be included that represent the position or positions that with greater depth performs that function, at all times some of the positions may belong to other areas, as is the case of the Industrial safety and internal relations manager (IS&IRM), that can appear in many functions. In this table 1, it will use some abbreviations: C&R by Compilation and Reception, HR by Human Recurs, IL by Inverse logistic, IS&IR, by Industrial safety and Internal relations, IS&IRM, by Industrial safety and internal relations manager, Mg by manager, P-S, by plant shutdown, R&D by Research and Development, and S&S by Security and Safety, as already it has been used throughout the work. Equally in table 1 and all work, when the terms safety or security are used as qualifiers, refers to the activity is performed safety and so to ensure security, respectively. Although whether or not they have appeared in the form explicit in other works, the functions listed here have been taken, modified or inspired, among other of: Akter [22]; Bernechea & Viger [21]; Mwanaumo [23]; Rashid & Rashid [2], but mainly of: Barreto [9]; García, Hernández & Hernández [8]; Guerrero et al. [10]; Hernández, García & Hernández [6,7,24]; Jeney et al. [25] and of all the works mentioned by them, to examine positions of the MoLoBaC.

Table 1 – Functions of the positions of MoLoBaC that can help a better S&S

Area: Procure.	
01	Establish policies for the selection of suppliers of the organization, to help ensure the S&S. 04.
02	Make constant monitoring of suppliers. 04.
03	Help keep clear the areas where products that reach the organization are received. 04, 03, 02, 01, 42.
04	Establish clear policies handling of hazardous products. 03, 02, 42.
05	Provide conditions to ensure reception safety, of all the raw material that reaches the organization. 03, 42.
06	Have strict control of all other inputs that are acquired by the organization. 02.
07	Ensure that suppliers arrives information security. 04, 03, 02, 18.
08	Take measures to a reception security of everything that comes to the organization. 04, 03, 02.
09	Take care that the inputs received by the organization do not contain harmful substances for staff. 04, 03, 02, 42.
Area: Maintenance.	
10	To establish political of maintenance safety, for the organization. 09, 42.
11	Keep a record of performance of all machines and equipment of the organization. 09, 06.
12	Be aware of any possibility of sabotage that might occur on equipment and machinery. 09, 06, 42.
13	Supervise all dangerous machinery, always under the protective measures required. 09, 42.
14	Ensure that preventive maintenance is carried out as scheduled. 06.
15	Provide conditions for preventive maintenance safety. 06.
16	Ensure that equipment and machines in the entire organization properly play. 09, 06, 08, 42.
17	Schedule replacement of machinery and equipment. 08, 09.
18	Make a very careful monitoring of any organization or staff recruited to perform major maintenance work. 07.
19	Having strict control of personnel outside the organization during major maintenance (P-S). 07.
20	Take special measures to ensure the safety of personnel involved in major maintenance (P-S). 07, 42.
21	Caring major maintenance security is always done. 07, 18.
22	Analyze all possible risks during P-S in particular risks: mechanical, physical, chemical, ergonomic, electrical, biological and environmental conditions. 07, 42, 09.
23	Provide personnel involved in P-S with all the necessary equipment for their safety. 07, 42.
Area: Inventories.	
24	Establish policies for the management of inventories, to avoid shocks that could interfere with the S&S. 14.
25	Use the inventory models that allow the organization to have the best controls. 13, 14.
26	Ensure an adequate management of the equipment and spare parts. 12.
27	Take care to keep available all the materials and equipment for the safety which the organization required. 12, 42.
28	To be sure that what is contained in inventories match what is stored in warehouses. 14, 12, 21.
29	Handle an inventory system security. 14, 18.
30	Providing the necessary equipment, to prevent fires and its spread. 12, 02, 04, 42.
Area: Order processing.	
31	Be aware that customer orders have no malicious intent. 25.
32	To maintain a permanent monitoring of customers. 25.
33	Establish policies for materials handling safety. 24.

34	Take all the relevant security measures with respect to machines and equipment in motion. 24, 42, 09.
35	Be aware that all media and places of displacement are free and in good conditions of use. 24, 42, 01.
36	Take care that the staff is not subjected to excessive physical efforts. 24, 42.
37	Design equipment, processes and products safety. 23, 42.
38	To have a politics of industrial design that the security takes care. 23.
39	To assure that the products in the stores should be distributed of way of doing a safety picking. 22, 21.
40	To take care for the safety of the personnel that it realizes the process of picking. 22.
41	To establish special measurements for the handling of dangerous materials or of particular conditions. 22, 24.
Area: Physical distribution.	
42	Establish policies S&S for the dispatch and distribution. 27, 29.
43	Ensure that the organization is working with the channels that provide greater S&S. 28, 29, 42.
44	To maintain a strict control of the distribution channels in regard to security concerns. 28, 29.
45	Ensure a dispatch safety. 27, 42.
46	Take care that the dispatch and distribution is made by minimizing physical efforts. 27, 29.
47	Maintain a constant monitoring of the Cross-Docking points, to ensure the S&S in the same. 29, 28, 27.
Area: Transportation.	
48	To establish political of transport S&S. 34, 42.
49	Take all the necessary safety measures if must be transporting hazardous materials. 34, 33, 32, 42.
50	Consider aspects of S&S at the time of establishing the fleet of the organization. 32, 34, 42.
51	Ensure that all the routes used are S&S. 33, 34, 42.
52	To do efforts to use processes of packed those are more possible safety. 31, 42.
53	To guarantee the use of packing that do not damage the environment and that do not affect to the personnel. 31, 41, 42.
54	To try that all the facilities of the organization are located in places S&S. 30, 42.
55	Establish measures to ensure that transport personnel are not subjected to exhausting working days. 33, 34, 32.
Area: Inverse logistics.	
56	To establish political of safety handling, of all the products that return to the organization. 38, 36, 37, 42.
57	To guarantee that the C&R does not represent risks for the personnel. 36, 38
58	To stay awake so that places where the materials of IL are received and classified, are in suitable conditions. 37, 36, 38.
59	To be attentive to the classification and future use of the products of IL. 37.
60	To take care that there is achieved the best possible use of each of the products that come for IL. 37.
61	Collaborate in the minimization of by-products, waste and scrap. 37, 10, 42.
62	Ensure the elimination of waste in the form most safety possible. 37, 38.
63	Ensure that the products and by-products from the IL, are stored in the appropriate manner. 38, 21.
64	Perform proper management of waste and all effluent arising in the organization. 37, 38, 42.
Area: Intrinsic to logistics.	
65	Ensure that the different areas of the organization have adequate lighting and ventilation. 01, 42.
66	Ensure that different areas have sufficient space to avoid any overcrowding. 01.
67	To establish in all the areas the sufficient escape routes, for emergency cases. 01, 42.
68	Take care that the machines and equipment have sufficient space to facilitate maintenance safety. 01, 09, 42.

69	To assure that the facilities should have sufficient sanitary services, including drinkable water for the whole personnel and of being necessary, showers, for the personnel that needs it. 01, 42.
70	To guarantee a suitable distribution of the spaces so that all the activities could be realized S&S. 01.
71	Make them available in good condition immediate shelters for disaster. 01, 42.
72	Pursue a policy of total quality in terms of S&S, in the sense detect failures as early as possible. 05, 42.
73	Carry out a constant monitoring of the processes to ensure the S&S. 05, 42.
74	Using the location of the different facilities as an element of S&S. 30, 42.
75	Promote policies duplication of equipment in remote locations, as a measure of security. 30, 18, 42.
Area: Supported by logistics.	
76	To take in consideration the S&S in any project of expansion. 15, 39, 42.
77	Perform forecasting to anticipate accidents. 35, 42.
78	Start up projects that contribute with the S&S. 39, 42.
79	Provide through the forecasts situations that could compromise the security of the organization. 35, 42.
80	Ensure that all the projects carried out under the strictest standards of S&S. 39, 42.
Area: Supporting logistics.	
81	Ensure that the minimization of costs, not translates into problems for the S&S. 10.
82	Establish appropriate budgets for the S&S. 11.
83	Use the constant analysis of the markets and consumers to improve the S&S of the organization. 20, 42.
84	To guarantee the conditions to support the cleanliness, the cleaning and the hygiene in all the organization. 26, 42.
85	To offer the necessary training to the personnel, so that they handle of form S&S his respective equipment. 26, 42.
86	To support a constant offer of workshops and courses so that the personnel improves his handling of the S&S. 26, 42.
87	Monitor the availability of first-aid equipment in all areas of the organization. 26, 42.
88	Always be attentive to the spirit of each of the employees, to minimize negative effects on the S&S. 26, 42.
89	Collaborate to ensure the security of confidential information for each employee. 26, 18, 42.
90	Remain attentive to the legal framework which may affect the S&S of the organization. 40.
91	To establish all the political ones of legal protection against to situations of risk of security. 40.
92	Convert the measures for protecting the environment in improvements of the S&S of the organization. 41.
Area: Information.	
93	Establish policies and standards relating to the information systems and the networks of the organization. 18, 19.
94	To realize constant investigations, which allow to offer progress in the field of the S&S. 19.
95	Devise systems that allow the organization to the detection of failures as early as possible. 18, 17, 19, 42.
96	Contributing to discover innovations that protect personnel and the organization. 19, 42.
97	Ensure the functioning of equipment and programs, providing backups in case of internal faults or environment. 18.
98	Care that virtual channels are not a way to allow attacks on the organization. 16, 18, 42.
99	Analyze constantly needs new strategies in the management and dissemination of information. 18.
100	Be up to date with new Information Technologies, including digital security. 18.
101	Working for the acquisition of equipment offering high security. 17, 18.

102	Acquiring software, equipment and tools that enable them to prevent any abnormal situation. 17, 18, 42.
103	Establish alternate mechanisms in case of failure of any system. 18, 19, 17.
104	Create models that detect any violation of preventive measures. 18, 42.
105	Ensure secure communication channels, in the case of sabotage attempts. 18.
106	Keep constant track of the information flowing to and from the organization. 18.
107	Analyze all accidents and failure of systems that occurred, for very simple they seem. 18, 42.
108	Evaluate and assume the new technologies to improve the S&S. 17, 42.
Area: Costumer service.	
109	Set all policies relating to the S&S of the Organization. 42.
110	Act jointly with state institutions to improve the security of the nation and the organization. 43.
111	Take advantage of good relations with consumers so that they assist in the security of the organization. 44.
112	Receive the support of all stakeholders to improve the S&S of the organization, especially the security. 43.
113	To visualize and to establish all the plans of contingency, to minimize any negative impact in the society. 43.
114	To do analysis permanently of the risks to which the organization can be submitted. 42.
115	To analyze all the risks that the employees could suffer. Especially risks of type: mechanical, physical, chemical, ergonomic, electrical, biological and for the environmental conditions. 42, 41.
116	To develop methods for the prevention of accidents and of insecure situations. 42.
117	To take measures to minimize the dust, smoke and other impurities that could affect to the personnel and the machineries. 42.
118	To take care that permanently the routes of escape are free of obstacles.42.
119	To have material and to guarantee the protection of any person who visits the organization. 42, 43.
120	Create safety circuits tour to every visitor to the organization. 42, 43.
121	To establish managerial indicators for the performance in S&S. 42.
122	To guarantee a handling of flow safety in the whole organization. 42.
123	Care that all the workstations respond to ergonomic designs. 42.
124	Generate preventive measures that help to sustain the S&S. 42.
125	Take measures to reduction of internal contamination in the organization. In any case to guarantee the equipment of protection front the same one, for the whole personnel. 42, 41.

For an organization to have a better management of the S&S, should include in its vision, mission, and Guiding Principles, but in addition, can improve their performance in these areas through the logistics, as can be seen through the 125 functions of table 1. From this table there can be extracted functions of the logistics that help a better safety, or functions that support the security and even functions that sustain the S&S in joint form, as is summarized in table 2. Many of these functions with only its statement its contribution is seen to the S&S, others have a little more indirect applications, but in any case here have been grouped together a large amount of logistics functions that contribute decisively in the S&S of an organization. However it is not possible to think that with only the functions presented here are sufficient to ensure a good handling of the S&S in an organization, but certainly reveal how important it can be the logistics to have an adequate management of this important aspect of business activity.

In terms of distribution can be seen in table 2, that the greatest number of functions are more closely related to safety, more than a 42%, followed by the functions that are involved with greater emphasis on the S&S, they are a little more than 35%, while covering the main way security are more than 22%. However this cannot think that the security has been less covered, because, as discussed, all functions directly or indirectly, cover both aspects, the safety, as the security.

Table 2 – Functions that support every aspect: Security, Safety and S&S

Aspect that the functions cover		
Security	Safety	S&S
2, 7, 8, 12, 19, 21, 25, 28, 29, 31, 32, 38, 44, 75, 79, 89, 91, 97, 98, 99, 100, 101, 102, 103, 105, 106, 110, 111.	3, 4, 5, 10, 13, 15, 16, 20, 22, 23, 26, 27, 30, 33, 34, 35, 36, 37, 39, 40, 41, 45, 46, 49, 52, 53, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 77, 84, 87, 113, 115, 117, 118, 119, 120, 122, 123, 125.	1, 6, 9, 11, 14, 17, 18, 24, 42, 43, 47, 48, 50, 51, 54, 70, 71, 72, 73, 74, 76, 78, 80, 81, 82, 83, 85, 86, 88, 90, 92, 93, 94, 95, 96, 104, 107, 108, 109, 112, 114, 116, 121, 124.

With the functions presented in the Table 1 and its organization, according to their greater impact on safety, security or in both, as shown in Table 2, it can be passed to present some conclusions and recommendations. Although the relationship of some of these functions with the safety and security are obvious, others are not so, however, escapes the objectives of this work make this deeper discussion.

4. CONCLUSIONS AND FUTURE RESEARCHS

The Table 2 shows how some of the functions played by the different positions of the Logistic Model Based on Positions (MoLoBaC), that can be of great help to improve the performance of an organization as to what safety and security (S&S) concerns. These functions, which are only represented by a number in Table 2, were expressed in more detail in Table 1, where also it is possible to see to that area of the model they belong and to the position or the positions, which they represent.

This allows us to affirm that it reached the general objective and specific objectives of this work, since it could detect a set of logistics functions, that to fulfill them in a proper manner, will improve all aspects relating to the S&S of an organization and this vision was achieved through the MoLoBaC, that was a principal component of the objective.

Detecting this relationship between the different functions and the safety and security also allows it to view the application of all these functions based on the positions of the Logistical Model Based on Positions are applicable to any company, whether large, medium or small companies.

From here arises as a line of research, the continue deepening this relationship between business logistics, through MoLoBaC and S&S of a company. This search on like improving the S&S, could lead to establish management indicators, through the Logistic Model Based on Indicators for Positions (MoLoBaICa), which would allow a better monitoring of important aspects of organizational work. Another line of research can continue in the immediate future it is to justify deeper relationships of each of the functions presented with the safety, security and safety and security (S & S) together.

5. REFERENCES

[1] Mattson, M.: *Promoting safety in organizations. The role of leadership and managerial practices*, Doctoral dissertation, Stockholm University, Stockholm, Sweden 2015.

[2] Rashid, M.M.U., Rashid M.A.: *Healt and safety environment of readymade garment industry in Bangladesh: A case study of Zaheen knitwears limited*, Manarat International University Studies, 4/1(2015), 71–82.

[3] Hao, R., He W., Zhang Ch.: *Comprehensive estimation of the economic security of logistics industry – Based on DEA model*, Journal of Scientific & Industrial Research, 74(2015), 381–386.

[4] Caputo, A.C., Palagagge P.M., Salini P.: *A multicriteria knapsack approach to economic optimization of industrial safety measures*, Safety Science 51(2013), 354–360.

[5] Magnusson, H.: *Did the message go through? A qualitative study on communication-mapping as a safety assessment and development tool at LKAB*, Master dissertation, Luleå University, Luleå, Sweden 2010.

[6] Hernández R., J.G., M.J. García, G.J. Hernández: *Social Aspects of Reverse Logistics and Knowledge Management*, In A. K. Goel, P. Singhal (Eds.), Product Innovation through Knowledge Management and Social Media Strategies. IGI Global: USA, 2016, 65–93.

[7] Hernández R., J. G., M. J. García G., G. J. Hernández G.: *Logistics, Marketing and Knowledge Management in the Community of Consumers*, S. Buckley, G. Majewski, A. Giannakopoulos (Eds.), Organizational Knowledge Facilitation through Communities of Practice in Emerging Markets. IGI Global: USA, 2016, 245–270.

[8] García, M.J., Hernández, G. G.J., Hernández R. J.G.: *Knowledge management through the Material Handling Manager,* In G. Dukic (Ed.), Proceedings ICIL 2014, University Zagreb: Croatia, 2014, 264–272.

[9] Barreto O., E.A.: *Gestión del conocimiento a través del Gerente de Proyectos de un modelo logístico*, Master disertación, Universidad Metropolitana, Caracas, Venezuela 2012.

[10] Guerrero M., L.E., Hernández G. G.J., García G. M.J., Hernández R. J.G.: *Indicators and the Picking manager of the Logistic Model Based on positions,* In G. Dukic (Ed.), Proceedings ICIL 2014, University Zagreb: Croatia, 2014, 273–282.

[11] García G., M.J., Hernández G. G.J., Hernández R. J.G.: *A Methodology of The Decision Support Systems applied to other projects of Investigation,* In Mehdi K. (Ed.), Encyclopedia of Information Science and Technology, Third Edition, IGI Global: USA, 3(2014), 1978–1990.

[12] Pishvaee, M.S., Torabi S.A.: *A possibilistic programming approach for closed-loop supply chain network design under uncertainty*, Fuzzy Sets and Systems 161(2010), 2668-2683.

[13] Cardoso, S.R., Barbosa-Póvoa A.P.F.D., Relvas S.: *Design and planning of supply chains with integration of reverse logistics activities under demand uncertainty*, European Journal of Operational Research 226(2013), 436–451.

[14] Pishvaee, M.S., Razmi J., Torabi S.A.: *Robust possibilistic programming for socially responsible supply chain network design: A new approach*, Fuzzy Sets and Systems 206(2012), 1–20.

[15] Winkler, I.S.: *Case study of industrial espionage through social engineering*, In Proceeding of the 19th Information Systems Security Conference, 1996, 1–7.

[16] Colwill, C.: *Human factors in information security: The insider threat – Who can you trust these days?*, Information Security Technical Report, 14/4(2009), 186–196.

[17] Kabay, M.E.: *Information Warfare*, In The NCSA guide to enterprise security, McGraw Hill, 1996.

[18] Crowley, E.: *Information System Security Curricula Development*, In Proceeding of the 4th conference on Information technology curriculum, (2003), 249–255.

[19] Azadeh, A., Sheikhalishahi M.: *An Efficient Taguchi Approach for the Performance Optimization of Health*, Safety, Environment and Ergonomics in Generation Companies, Safety and Health at Work 6(2015), 77–84.

[20] Khdair, W.A., Shamsudin F.M., Subramanim Ch.*: Improving safety performance by understanding relationship between management practices and leadership behavior in the oil and gas industry in Iraq: A proposed model*, International Conference on Management and Artificial Intelligence, IPEDR 6(2011), 85–93.

[21] Bernechea, E.J., Viger J.A.: *Design optimization of hazardous substance storage facilities to minimize project risk*, Safety Science 51(2013), 49–62.

[22] Akter, F.: *Study on the knowledge on fire safety management and preventive actions of selected garments factory worker in Dhaka city*, Journal of Innovation & Development Strategy 8/2 (2014), 15–21.

[23] Mwanaumo, E.M.: *An integrated approach to multi-stakeholder interventions in construction health and safety*, Doctoral dissertation, Johannesburg University, Johannesburg, South Africa 2013.

[24] Hernández R., J.G., García G. M.J., Hernández G. G.J.: *Teaching Enterprise logistics through indicators: Dispatch manager*, K. Grzybowska (Ed.), 7th Scientific Conference 'Economy and Efficiency – contemporary solutions in logistics and production', Poznan, Poland, 2012, 7–24.

[25] Jeney, A., Hernández J.G., García M.J., Hernández G.J.: *Generation and Knowledge Management System Through the information and networks manager,* In Delener et al. (Eds.), GBATA2015 Reading Book, GBATA: USA:, 2015, 244–251.

EVALUATION OF ASPECTS OF LOGISTICS EFFICIENCY OF A PRODUCT IN THE PRODUCTION ENTERPRISE

Maciej BIELECKI[1], Magdalena HANCZAK[1]

[1]Lodz Univertsity of Technology, Faculty of Organization and Management,
Department of Production Management and Logistics
215Wolczanska, 90-924 Lodz,
Poland

Abstract:

The issue of logistic efficiency of a product is a newer concept whose main purpose is to focus the attention on the role of the product itself in efficient logistics management of production enterprises. The logistics efficiency of a product is defined and the concept of its evaluation is presented. The research results are presented, comprising the selection of products for assessment and the assessment of their selected aspects of the logistics efficiency. The article provides a summary indicating the advantages and disadvantages of the applied methods and guidelines for further research work.

Keywords:

product, logistics, efficiency, evaluation

1. INTRODUCTION

Logistic aspects should undoubtedly constitute a part of operation strategy of every production enterprise. A product, even one completely fulfilling expectations of clients, may not bring a company the expected profits if its characteristics and properties do not account for the necessity of subjecting it to various processes, including logistic ones, in production preparation stage: in the area of resourcing the production process with the necessary materials, and after manufacturing the product: in the area of distribution and customer service. More and more frequently the achievement of long-term objectives of a company should therefore include logistic aspects such as the choice of suppliers, the choice between the company's own and external transport and storage service, as well as defining the way of reaching clients by means of distribution network [1].

The authors emphasise the fact that making specific strategic decisions connected with logistics should depend on exhaustive analysis of characteristics and properties of the product offered by a company. Many enterprises assume that their products are unchangeable and they seek ways of bettering the way in which they operate and of lowering the running costs in the organisation of particular processes. However, there are situations when slight changes in the product design can bring better results than increasing efficiency of specific processes throughout the company. It becomes vital to introduce the notion of logistic efficiency of a product that includes the vulnerability of a product to transport, storing, packing, order service and stock management [2–4]. The issue of logistic efficiency and an attempt of formulating the concept of its evaluation are important not only from the point of view of running an enterprise but also interesting due to the number of problems related to it.

2. THE CONCEPT OF EVALUATION OF LOFISTIC EFFICIENCY OF A PRODUCT

A logistically efficient product is defined as “a material object of market exchange which possesses a set of features and properties that enable it, within the internal dimension of an organization, to move through supply, production and distribution areas, and, in the external dimension of an organization, enable logistic management to effectively and efficiently integrate handling orders, managing supplies, storing, packaging and transport with external subjects as a part of supply chain” [5]. It should also be noted that a logistically-efficient product enables both the producer and customer to gain benefit. As the interests of both sides are often contradictory, an attempt to combine the benefits will result in creating an ‘imperfect’ product, but one that will facilitate executing logistic processes and one satisfying to a client [6].

In order to be able to manage logistic efficiency of a product it is necessary to assume a way of measuring it. During the analysis and evaluation of selected products, an original concept of evaluation was used. It was based on the following assumptions:

- the evaluation of logistic efficiency of a product should be comparative in its character (point to the assessed product that shows greater logistic efficiency);
- evaluation criteria should take the 7R rule into consideration;
- the evaluation should account for functional division of logistics;
- mark scale for each product should be binary {0;1}, while the number of marks given to a product in a specific aspect can be the same as for its counterpart;
- to precisely assess a product in terms of each aspect selected indicators can be used.

Taking the above assumptions and factors influencing logistic efficiency of a product for particular functions of logistics into consideration, the aspects of evaluation of logistic efficiency of a product were defined. The aspects were ordered in accordance with the elements of 7R rule and collected in the evaluation sheet (Table 1). In case of time and quality criteria aspects were assigned to each element of functional division of logistics. In other cases, no connections were found between all logistic functions and criteria that is why the number of aspects in individual criteria varies. When assessing products with the use of the proposed sheet 0 and 1 point should be assigned, where 1 is a positive mark and means that for a given product the assessed aspect is true (or closer to the truth than for other products). It is possible to give the same number of points to all products if there are no differences between them in a given aspect. A product that is given the greatest number of points can be considered more logistically efficient. The obtained results may be analysed in terms of each of the 7R criteria or of each of the logistic functions.

3. CHARACTERISTICS OF THE ANALYSED AND ASSESSED PRODUCTS

Research was conducted in an enterprise producing styrofoam profiles used in construction and other foam elements. The system of construction solutions consists of almost a hundred elements that can be combined like building blocks. The company assumes that a larger number of elements on offer means better design possibilities and quicker assembly of house constructions. This is due to the fact that that the amount of labour on construction site is reduced. In order to facilitate the assembly of shoring, each element has grooves that make cutting easier and special locks used for combining the blocks.

The company's products can be divided according to the construction criterion into the following categories:

- foundation slabs,
- wall construction elements,
- ceiling construction elements, and
- roof construction elements.

Table 1 – An evaluation sheet of logistic efficiency of products

CRITERION	LOGISTIC FUNCTION	ASPECT	MARK	
PRODUCT			Product 1	Product 2
TIME	*Order service*	There is a smaller number of precisely defined variants of a product		
	Stock management	Product consists of a smaller number of elements		
		Time of production is shorter		
		Time of preparing production is shorter		
	Storing	No preparatory activities are necessary for storing the product		
	Packaging	Product packaging facilitates storing, transport and manipulation		
		Product packaging provides information necessary to identify the product		
	Transport	Product has features facilitating its loading and unloading		
SPACE	*Stock management*	Raw materials and product parts stock takes less space		
	Storing	Product stock takes less storage space, product can be piled		
	Packaging	Packaging saves space and area it takes		
		Packaging stock takes less space		
	Transport	Product dimensions allow to better use the room inside means of transport		
COSTS	*Stock management*	Material consumption of a product is smaller		
	Storing	Product does not require special storing conditions		
	Packaging	Material consumption of the packaging is smaller		
	Transport	Product does not require special transport conditions or special solution in terms of transport infrastructure		
QUALITY	*Order service*	A unit of the product can be precisely defined		
	Stock management	Product demend is easier to forecast		
	Storing	Product does not expire (had a longer expiry date)		

	Packaging	Packaging protects the product against decrease in value		
	Transport	Product has no features hindering transport		
NUMBER/ AMOUNT	*Stock management*	Product consists of standard parts (elements)		
	Storing	Product can be manufactured in smaller batches		
CLIENT	Product price is lower			
	Product quality (durability, functionality) is higher			
	Product service is provided			
	There are additional benefits for a client			
	There are no additional costs for a client			
TOTAL MARK				

The wall construction elements include several categories of products: MC product line, MCF product line and MCFU product line. The major difference between these lines lies in the way of combining the sides of an element (Figure 1). The sides can be joined permanently: with foam when moulding a profile (products denoted as MC) or with an inserted lacing (MCF); they can also be detachable – joined with a slid-in lacing (MCFU). The application of lacing is advisable in buildings of high fire hazard as they are made of non-flammable materials. Using the slid-in lacings has yet another advantage – the elements can be assembled on construction site which results in saving space and costs of transport.

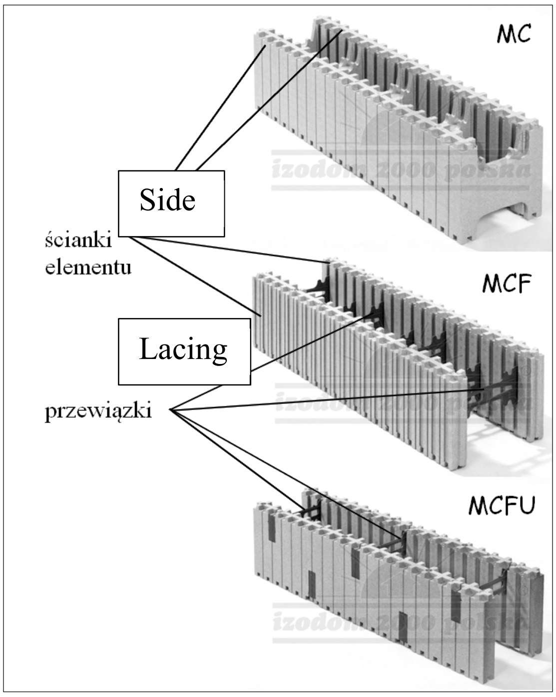


Figure 1 – Joining sides of the elements of wall construction

4. RESEARCH METHODS AND RESULTS

The aim of the conducted study was collecting information that would allow to analyse and assess logistic efficiency of the company's products. Detailed aims of the study included identifying:
- elements of the largest share in sales,
- basic characteristics and properties of products, and
- make-up elements of logistic efficiency of final products.

The study was divided into two stages. The initial stage aimed at identifying elements of greatest significance for the company in terms of sales share and comparing their characteristics and properties. This stage included ordering data provided by the company in the form of hard-copy records, invoicing system output and product catalogue available on the company's website. The conclusions drawn after the initial stage became the basis for designing guidelines for the second stage of the study.

The second stage was the main stage of the study. An interview with the production manager of the company was supposed to indicate how the final products influenced the execution of consecutive areas of logistic efficiency. The interview was conducted at the company's site based on instructions (a list of questions). The interview consisted of two parts: the first, introductory part was based on general conversation about the products, aiming at defining the most important differences in managing the products' supply, production and distribution from the point of view of the production manager; the second part was aimed at obtaining specific information about the products. The questions concerned functional and stage division of logistics:
- storing,
- transport,
- packaging,
- order service,
- stock management,
- supply,
- production,
- distribution, and
- costs for the clients as reflecting the 7R rule (right product, quantity, condition, place, time, customer, price).

The initial study indicated the necessity to further analyse the elements of wall construction as those of the largest share in sales. MC 2/35 and MCFU 2/35 elements were selected.

5. ANALYSIS OF RESEARCH RESULTS

Comparing products MC 2/35 and MCFU 2/35 based on the information collected during the interview, differences in the following aspects could be noted:
- order service; assembling orders;
- stock management: forecasting sales, number of moulds used in production of an element, one-shift production, material consumption of foam, managing the stock of lacings, standardization (applying elements in other products), managing the stock of packaging materials;
- storing: occupied storage space, required organization of the warehouse;
- packaging: ways of packaging the elements;
- transport: the volume of transported products, the number of runs;
- factors important for clients: price, fire-resistant properties.

Each of the analysed products has its advantages and disadvantages in terms of logistic efficiency. They are presented in Table 2 and Table 3 taking into consideration the properties that distinguish the studied products (the advantages of one become the disadvantages of the other). The conducted analysis was comparative in its character, due to which further considerations do not include common aspects of the two products. The company does not keep a strict record of worktime and of the flow of materials, neither does it adhere to time norms. Due to low repeatability of particular activities by workers, the study did not include measurement of time of performing specific actions and operations in case of the studied products. This made it impossible to calculate indicators and the conducted analysis was, in many cases, qualitative not quantitative. The key in the study was the 7R rule.

Assuming the criterion of time of logistic service, the differences in production processes of MC 2/35 and MCFU 2/35 products concerned the following: assembling orders, managing stock, production time of batches of products and using tape for bundling the facings of the MCFU element.

Table 2 – Advantages and disadvantages of MC 2/35

Advantages	Disadvantages
▪ Sales of the product is equally distributed over time, which facilitates forecasting demand and planning production ▪ Production of the element uses one moulding machine (one mould is used in production) ▪ Lower price of the final product	▪ Higher material consumption of foam raw material ▪ Final product takes up more storage space ▪ Smaller amounts of product can be fitted into means of transport

Table 3 – Advantages and disadvantages of MCFU 2/35

Advantages	Disadvantages
▪ There is a possibility of applying the sides of the product (facings) in other MCFU elements ▪ Lower material consumption of foam raw material ▪ The final product takes up less storage space ▪ Larger amounts of product can be fitted into means of transport ▪ Fire-resistant properties	▪ Product sales vary over time, which makes it difficult to forecast demand and plan production ▪ Completing an order is more complex ▪ The necessity of managing the supply of lacing ▪ The necessity of managing the supply of facings used in several products ▪ Two moulds are needed in the production process (simultaneous work of two machines or prolonged production time) ▪ Separate storing of the supply of facings and lacing requires proper organisation of storage space ▪ The necessity of bundling the facing with into packages ▪ Higher price of the final product

Time-based analysis unambiguously showed that the flow of MC 2/35 within the company lasted shorter than in case of MCFU 2/35. Not all advantages of MC 2/35, despite being strongly tied to the product itself, were inherent to its characteristic and properties, for example, in case of production time – it was dependent on the moulds used in production. It would be sufficient to change the mould for MC, so that two 15-centimetre facings and two 5-centimetre facings were produced simultaneously, and the production time for both would be the same. This would also lead to solving the problem of assembling MCFU by bundling elements into sets of two facings instead of uniform packages. It could be then concluded that the process is better adjusted to the production of a monolithic MC 2/35 than to the assembled MCFU 2/35. It cannot, however, be concluded that MC 2/35 is more logistically efficient than MCFU 2/35, considering the time criterion.

6. EVALUATION OF LOGISTIC EFFICIENCY OF PRODUCTS IN TERMS OF TIME CRITERION

Applying the designed sheet, the evaluation of MC 2/35 and MCFU 2/35 products was carried out. Marks were given in each aspect in accordance with the conclusions drawn from the analysis of the study results.

Taking the time criterion into consideration, four out of eight aspects itemised in the evaluation sheet for logistic efficiency of a product were given positive marks. Both MC 2/35 and MCFU 2/35 have only one variant, which is why both had to be assigned one point for order service. It is not necessary in case of both products to perform any storage preparation activities, which is why this aspect was assessed uniformly. Different marks were given for the number of comprising elements and packaging that facilitates transport and manipulation. In the former aspect, MC was given higher marks, in the latter – MCFU (whose elements are bundled with the use of tape). In accordance with the explanation provided in the analysis of the study results, production time and production preparation time were not assessed in favour of any of the products as it does not depend on the product as much as it does on the organisation of the process.

Table 4 – Evaluation of logistic efficiency of selected products in terms of time criterion

Logistic function	Aspect	Marks for MC 2/35	Marks for MCFU 2/35
Order service	There is a smaller number of precisely defined variants of a product	1	1
Stock management	Product consists of a smaller number of elements	1	0
	Time of production is shorter	0	0
	Time of preparing production is shorter	0	0
Storing	No preparatory activities are necessary for storing the product (e.g. re-packaging)	1	1
Packaging	Product packaging facilitates storing, transport and manipulation (e.g. it is fitted with handles, non-slippery, normalized)	0	1
	Product packaging provides information necessary to identify the product	0	0
Transport	Product has features facilitating its loading and unloading	0	0
Total		3	3

In the evaluation of the aspects of logistic efficiency of a product connected with the criterion of time, both studied products obtained the same number of marks.

7. CONCLUSION

The article has presented a concept of the evaluation of logistic efficiency of a product according to one of the criteria – that of time. The research also allowed to assess other 7R criteria, but the requirements of the conference resulted in limiting the study to only one evaluation criterion.

The presented concept is only an introduction to the authors' research but it still allows to notice its advantages and disadvantages.

Simplicity, lack of the need for complex calculations and clear demonstration the aspect that should be changed are among the advantages of the concept.

Another benefit of the proposed evaluation concept is undoubtedly systemic approach. The model accounts for many aspects bot in functional approach and in reference to the 7R rules. It is possible that the list of the aspects is not yet complete, but the simple construction of the tool makes it possible to add criteria typical of assessed products, if needed.

The disadvantages of the model include the necessity of performing the evaluation in strictly defined conditions. The evaluation is comparative – it does not produce concrete result that can be applied in many contexts but only points to a better product. The products should be similar (in terms of application, function). The evaluation is largely dependent on the decision-maker and so it is subjective. Not all aspects can be assigned indicators that would reflect the features of a product quantitatively. In many cases the evaluation is qualitative and the results of evaluation made by different people will not be comparable. It also has to be noted that when assigning marks the products need to be carefully analysed so that their actual characteristics and properties – the elements under evaluation – are separated from external factors related to organization of the production process and the designed way of executing particular logistic activities.

The presented concept of the evaluation of logistic efficiency of a product, the result of the authors' research work, is an important element of constructing a complete model of logistic efficiency of a product that, according to the authors, is a part of a broader concept of Total Logistics Management [1,7].

8. REFERENCES

[1] Szymonik, A., Bielecki M.: *Bezpieczeństwo systemu logistycznego w nowoczesnym zarządzaniu* [Security of a Logistic System in Modern Management], Difin Publishing House, Warszawa 2015.

[2] Bielecki, M.: *Miejsce podatności ładunku w koncepcji logistycznej sprawności produktu* [The Position of Transportability in the Concept of Logistic Efficiency of a Product], Logistyka [Logistics], 5(2013).

[3] Bogdanowicz, S., *Podatność. Teoria i zastosowanie w transporcie* [Vulnerability. Theory and application in the transport], Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2012.

[4] Kroger, W., Zio E.: *Vulnerable systems, Springer*, London 2011.

[5] Bielecki, M.: *The influence of a logistically efficient product on the logistics of a manufacturing enterprise*, Annals of Faculty Engineering Hunedoara – International Journal of Engineering, 6(2013).

[6] Bielecki, M.: *The Logistical Efficiency of the Product in Logistics Strategies of Manufacturing Enterprises*, Carphatian Logistic Congress, Congress proceedings, CD version, Jesenik2012,

[7] Bielecki, M., Madej M.,: *The Role of Packaging And the Packaging in Logistical Efficiency of the Product Shown on the Example of Small Manufacturing Enterprises*, In: *Product and Packaging. Tendencies for Development in Logistics*, J. Lewandowski, A. Walaszczyk, M. Sekieta (Eds.), Monograph Lodz University of Technology, Lodz 2012.

GENERATION AND MANAGEMENT KNOWLEDGE. A VIEW FROM THE MANAGER OF PACKING

Jerónimo DE BURGOS J.[2], María J. GARCÍA G.[1], Gilberto J. HERNÁNDEZ G.[1], José G. HERNÁNDEZ R.[1]

[1]Minimax Consultores, C. A.
Urbanización El Bosque Chacaito, Caracas,
Venezuela
[2]Universidad de Almería
Cañada de San Urbano, Almería,
España

Abstract:

There is concern in organizations by generation and knowledge management. Taking advantage of the relations of the managerial logistics with all the areas of the organization, it has emerged a line of research to help generate and manage knowledge, using the Logistic Model Based on Positions (MoLoBaC) that studies the logistics through functions. For this work Packing manager of MoLoBaC will be used. Of there the objective of this work: To show as it is possible to generate and to manage the knowledge in an organization with a vision of the Packing manager of the Logistic Model Based on Positions.

Keywords:

Knowledge Management, Business Logistics, Logistics models, MoLoBaC, Packing manager

1. INTRODUCTION

Concern about knowledge management in organizations is permanent, given the impact it can have on them (De Long & Seemann [1]; Madeira, Vick & Nagano [2]; Makhsousi, Sadaghiani & Amiri [3]; Malik & Malik [4]; Wagner [5]). Sometimes the knowledge acquired by organizations, it is received by its employees and is mostly external knowledge, that can arrive by way more personal than institutional (Nzui [6]). However, as valuable or even more valuable than external knowledge is the knowledge generated in the organization. Of this internal knowledge their generation must be stimulated and it should manage to get the same the greatest benefit possible (Al-Khouri [7]; Riungu [8]).

On the other hand, is known the high impact of business logistics in almost all areas of an organization, this is an advantage for using it to understand the organization, but it is a difficult to its teaching. For this difficulty to teach the logistics, have been created in the academy, four qualitative-quantitative models to facilitate their study (Barreto [9]; García, Hernández & Hernández [10]; Guerrero et al., [11]; Hernández, García & Hernández [12,13]; Hernández et al., [14]; Jeney et al., [15]). Each of these four models tries to explain the logistics from a different point of view: the Supply, Production, Distribution and Inverse Logistic model (LSPDI, in Spanish el modelo Logístico, Abastecimiento, Producción, Distribución e Inversa [LAPDI]) studies the logistics through the logistics flows; the Logistic Model Based on Positions (LoMoBaP, in Spanish Modelo Logístico Basado en Cargos [MoLoBaC]) takes into consideration, for study, all the functions that realize those who play positions related to the managerial logistics; the Logistic Model Based on Indicators for Positions (LoMoBaIPo, in Spanish Modelo Logístico Basado en Indicadores de Cargos [MoLoBaICa]), it overlaps to MoLoBaC and studying logistics through performance indicators and the Logistic, Strategic, Tactical, Operational with Inverse Logistics Model (STOILMo, in Spanish Modelo Logístico, Estratégico, Táctico, Operativo con logística Inversa [MoLETOI]), that, based on the three components of the administrative pyramid the: Strategic, Tactical and Operative and including the inverse logistics, it studies the managerial logistics.

With the second of these models, the MoLoBaC, in the year 2012 (Hernández, García & Hernández [16]) there began a line of investigation that there consists of studying the generation and knowledge management in the organizations from the positions of the MoLoBaC, among others have been used: the Projects manager (Barreto [9]), the Material handling manager (García, Hernández & Hernández [10]), the managers associated with the area of inverse logistics (Hernández, García & Hernández [13]), the System information and network manager (Jeney et al., [15]) and the pioneering work where study the Customer service manager (Hernández, García & Hernández, [16]).

In this paper this line of research will continue and generation and knowledge management will be studied based on the functions performed by the Packing manager (PM) of the MoLoBaC. Hence the objective of this work is: To show as it is possible to generate and to manage the knowledge in an organization with a vision of the Packing manager of the Logistic Model Based on Positions. To achieve this general objective will include three specific objectives:

- To show the importance those have for the organizations the generation and knowledge management.
- Present Packing manager of MoLoBaC, emphasizing their multiple functions.
- Analyze through some functions of PM, as it is possible to generate and manage knowledge in an organization.

With regard to limitations and scopes, there will not be the case of any particular company. On the contrary, the analysis will be made through a hypothetical case, as broad as possible to give the study a universal validity.

1.1. Methodology

To achieve the general objective and specific objectives, it will make use of the Integrated-Adaptable Methodology for the development of Decision Support System (IAMDSS, in Spanish, Metodología Integradora-Adaptable para desarrollar Sistemas de Apoyo a las Decisiones [MIASAD]), which it was developed to create support systems, but because of its flexibility it adapts to different types of investigations (Barreto [9]; García, Hernández & Hernández [10,17]; Guerrero et al., [11]; Hernández, García & Hernández, [16]; 2016 [12,13]; Hernández et al., [14]; Jeney et al., [15]). MIASAD, addresses the investigations without passing through the development of hypothesis, but a set of steps are followed, which they are adapted to each situation, particularly. In this paper, following what has been done in the previously mentioned work will be used: a) to define the problem that, as is indicated in the objectives, is to show as it is possible generate and manage knowledge in an organization with a vision of Packing Manager (PM) of the MoLoBaC; b) develop a first prototype, whose main objective is to have a complete view of what will be research and the first thing to do is recognize users of the final product, in this case, because it is a scientific article, it will identify its main readers, which are all interested in studying how organizations can take advantage of the generation and knowledge management, especially those who are willing to discuss new approaches; to these first readers will be added all the scholars of the logistics, since all its aspects, especially those interested in the functions performed by those who have related positions to the logistics performance and particularly interested in the qualitative-quantitative models. Also, in the first prototype, the structure of the article is established, which in addition to this introduction will consist of three central chapters, in the first of them, will provide some very general comments on the generation and knowledge management, in the second chapter will be presented the PM, especially through some of its functions and in the third chapter, which comes to be the principal one of the work, it will presented as it is possible to generate and to manage the knowledge in an organization making use of functions of the PM of the MoLoBaC; c) search data, particularly on: generation and knowledge management, business logistics, the MoLoBaC and especially on the functions of its PM; d) to define alternatives, that consists of visualizing how it is possible to improve the generation and management of the knowledge in an organization through the functions of the PM; e) evaluate alternatives, see the feasibility of the proposed alternatives according to the objectives established; f) to select the best alternative, according to the previous evaluation and considering the secondary objectives, whether they are tacit or explicit; g) implement the chosen alternative, that is to say to establish all the mechanisms that allow that the select alternative could take to the practice and h) establishing controls, the mechanisms, that allows to recognize if the solution obtained, continues being valid in the course of the time.

In any case it is important to clarify that the chosen alternative, it can be a set of functions.

2. BRIEF COMMENTS ON THE GENERATION AND KNOWLEDGE MANAGEMENT

The organizations are interested in the knowledge, principally in the dynamic knowledge. As this aspect has been already studied in the works previously mentioned (Barreto [9]; García, Hernández & Hernández [10,17]; Hernández, García & Hernández [16]; 2016 [13]; Jeney et al., [15]), reading them it is recommended to have a deeper information, particularly the initial work (Hernández, García & Hernández [16]). In all these works, of many approaches that exist on generation and knowledge management, it has followed the work of Nonaka, Toyama & Konno (2000 [18]), since it presents in a simple form the spiral of generation of the dynamic knowledge or SECI model. Following the simplification, handled in Hernández, García & Hernández [16], Barreto [9] created a schema, which is shown in figure 1.

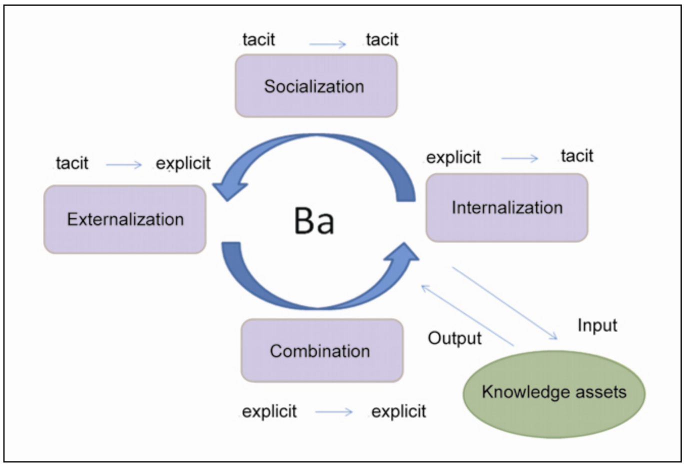


Figure 1 – Conceptualization of the model of Nonaka, Toyama & Konno. (source: Barreto [9]), based on Nonaka, Toyama & Konno [18]).

In addition to being used in the works previously mentioned (Barreto [9]; García, Hernández & Hernández [10,17]; Hernández, García & Hernández [16]; 2016 [13]; Jeney et al., [15]) and in other works that these authors quote, it is possible to find references to the SECI model or of theory of the spiral of Nonaka, Toyama & Konno [18] among others in the work of Al-Khouri [7]; Malik & Malik [4]; Minhas, Juzek & Berger [19]; Riungu [8]; Shahzad et al. [20].

As can be seen in Figure 1, SECI come to be the initials of Socialization, Externalization, Combination and Internalization, which they are the four fundamental processes that manages the spiral model, allowing trough them the exchange and generation of knowledge tacit-explicit-tacit. For this exchange of knowledge can take place there must be an environment Ba, which allows it. And this exchange of knowledge is generated and reinforced the knowledge assets, that Nonaka, Toyama & Konno [18] recognize: Experimental, Conceptual Systemic and Routine knowledge assets. To close these brief comments on the generation and management of knowledge and before proceeding to review the functions of the Packing manager, a definition of dynamic knowledge is presented: It is an intangible resource, that works as the center of gravity of the creation and is itself the process of creation, diffusion, transference, internalization and absorption of the knowledge, departing from the transformation and conversion of the tacit knowledge in explicit knowledge and continuously through a spiral, that makes this last explicit knowledge generated, in tacit knowledge, restarting the cycle. For all this, the dynamic knowledge is expansive and complex and is one of the most important sources of competitive advantage of organizations (Hernández, García & Hernández [16]; 2016 [13]).

3. THE PACKING MANAGER OF THE MOLOBAC

Before making any comment on the Packing manager (PM) it is necessary to clarify that in Spanish there is a series of terms: “recipientes, envases, empaques, embalajes and envoltorios”, that in translation to English, for the first two is used the word containers, for the remaining is used packaging and for the last also it is used wrapping. For this reason, at least clarification is required, in this work, will be used the terms containers, packaging and wrapping as synonyms. On the other hand, it is also important to make a reference to packaging primary, secondary, tertiary, transport packaging and load unit, taking for these concepts elements of Cervera [21]; Dahlborg & Johnsson [22]); Gurgel [23]; Jernberg & Svensson [24].

Primary packaging – it is in direct contact with the product. It is also known as packaging containment.

Secondary packaging – contains one or more primary packaging and removal does not affect the product. Usually it is a display package.

Tertiary packing – it contains and groups sets of primary or secondary packing and its main function is to unify the products for distribution. It may also be recognized as marketing packaging. An extension of the tertiary packaging is the transport packaging, that is that one where there are placed a group of secondary or principally tertiary packing to be transported towards the client.

Unit of load – it is a set of goods, principally of tertiary packing, that are stacked in a homogeneous way, usually on a palette, to facilitate their transport. It can also recognize as packaging mobilization.

Already to understand the PM, it should be clarified that the MoLoBaC consists of forty four positions, which are grouped into areas and these in turn in stages. In the Distribution stage, one of its areas is Transportation, is considered a mixed area, since integrates positions of different stages, it is integrated by the positions: Location manager (30), that is a position of the stage Generals of the company and Packing manager (31), Fleet manager (32), Routes manager (33) and Transport general manager (34), all of them own from stage Distribution. The numbers next to each position uses the model to identify. The PM, identified as position 31, it is located in this area, by its great interrelation with the remaining positions of the same. From here we start to say that the PM is responsible, those aspects that relate to all packaging to be used in the organization. Recalling that these packages have a dual function, logistics and marketing and even usually they have a legal function, since primary packaging for many products must meet certain legal regulations. So it is the responsibility of the PM the choice of packing and packaging materials and equipment and processes for their manufacture or use, as the case. This includes primary, secondary, tertiary and loading units containers (Gurgel [23]), and the definition and management of pallets used for mobilization. It will also be responsible for establishing the elimination, environmentally friendly, of all these packages and containers, as well as their sub products, waste and scrap.

Just like all positions of the MoLoBaC, this manager has much interaction with other positions of the model, in particular there stand out those of the area of transport, because the packaging must be adapted to the fleet and routes that sets the Transport manager, the Handling material manager (HMM), during the movement of containers and packaging and with the Picking manager, at the time of choosing and using the tertiary packaging, but especially with the Ethical Juridical consultant, by that there are legal aspects associated with the primary packaging and above all with the Marketing and Sales manager (M&SM), since the packaging is without a doubt a promotional item. And in the same way that the remaining positions of the MoLoBaC, its main objective is to satisfy the needs of the end customer. And similar to the realized in other works, to facilitate the understanding of the functions of the PM, before enumerating, be presented a couple of concepts: business logistics and management supply chain.

As expressed Hernández, García & Hernández [12], the enterprise logistics is centered in searching and achieving a greater satisfaction, present and future of the final costumer, and includes socio-environmental and ethical-legal aspects, organization planning, execution and control of all related activities related to the attainment, flow, gathering and maintenance of materials, products and services, since the raw material source, including there the costumers through inverse logistics, to the sale point of the finished product local or international, massive or enterprise, in a more effective and efficient, maximizing performance and the expected quality, minimizing waste, times and costs and using modern information technologies.

Supply chain is a wider concept than enterprise logistics, in the sense of its scope and is understood as all the logistic aspects that must be synchronized among the producers of raw material, finished products and both wholesale and retail distributors, so the costumer is attended adequately satisfying its real needs; the logistics aspects in which Supply Chain Management (SCM) is usually centered are: warehouse, inventories, localization and transportation, but in order to achieve a good SCM it is required a high integration of the information systems (Hernández, García & Hernández [12]).

3.1. The functions of the Packing manager

The need to ensure the care of all materials, throughout the process that begins with the finished product and even during production, until it is consumed by the final customer, coupled with the need to encourage the sale of products, makes that the Packing manager (PM) must realize a big quantity of intricate functions, which must fulfill very effectively and efficiently. Some of the functions to be performed the PM, are reflected in table 1, most of them taken based or inspired, among others, of Cervera [21]; Gurgel [23]; Kuvykaite, Dovaliene & Navickiene [25]; Saghir [26]; Theppituck et al. [27]; Vernuccio, Cozzolino & Micheline [28], but principally following functions similar to the presented in works where positions of the MoLoBaC are studied (Barreto [9]; García, Hernández & Hernández[10,17]; Hernández, García & Hernández [16]; 2013 [29]; 2016 [13]; Jeney et al., [15]). In the table 1, abbreviations are used such as, HM by handling materials, HR by Human Resources, ID by industrial design, IL by inverse logistics, ISIR by industrial security and internal relations, Mg by Manager, M&S by marketing and sales, M&SM by Marketing and Sales manager, PP by packaging processes, R&D by Research and development, SC by supply chain, SCM by supply chain management, S&E by spare and equipment. Some of these abbreviations have been already used and they will keep on using in rest of the work.

Table 1 – Some of the most important functions of the Packing Manager

Intrinsic to the position	
01	To define the political relative to everything related to the packing and PP of the organization.
02	Search, permanently, improvements in the packaging and PP.
03	Have a permanent control of the packing and PP that are used in the organization.
04	Schedule the acquisition of materials, machinery and equipment for the production or use of the packing.
05	Establish a clear classification of the different packaging according to application possibilities.
06	Decide when or what packages are to be acquired and which produced in situ.
07	To deepen in the protective function of the product that has the packaging.
08	Investigate and contribute to the creation of new packaging and PP adapted to the organization.
09	Identify the most appropriate packaging for each of the products according to each particular situation.
10	Work to achieve PP flexible and dynamic that can quickly be adapted to changing situations.
11	Analyze the patterns of consumption to take them into account when defining the packing.
12	Constantly review the PP, especially in response to their cost/service provided.
13	Study and maintain a constant review on the types of materials that may be used as packing.
14	Adapt the packaging of export products to the requirements of countries destinations.
15	Keep informed all the organization of any change made in the PP.
16	Study all manipulation of the product that may make the final customer, to adapt the packing to their needs.
17	Keep a record of the durability of the products for which the packaging can ensure.
18	Adapt the packing, especially primary, to the standards that set the market, while respecting the tacit codes that often exist in each region.
19	Be aware of the components of the packaging that can become scarce and determine a priori, replacement elements.
20	Request for all packaging and PP, the evaluation experts and users, to incorporate improvements.
21	Analyze the usual loads units, to adapt the tertiary packaging to the same.
22	Contribute to resolve, as soon as possible, any inconvenience that is present in the PP and use of packaging.
23	Pay particular attention to the packaging of products of special handling.
24	Stay in constant search for new ways to use the different packaging.
25	To try to adapt the packing to the purchasing power of the consumers.
26	To ensure the proper functioning of the equipment used for the PP.

27	Be aware of the rotation of the different products to avoid obsolescence of packaging and products themselves.
28	To try that the packing help in the impulsive buys.
29	Promote the appropriate use, to its potential, of the different packaging and PP that are managed in the organization.
30	Ensure that the packaging of products for supermarkets, who are touched by the customer through the packaging, to protect both, the product of contamination, such as customer being soiled by the product itself.
31	To ensure that the packaging, especially primary and secondary, enhance the product.
32	Enhance the packaging, in particular the primary, as an element of promotion and communication.
33	Take strict security measures in handling packages, especially if they are flammable or toxic products.
34	Make efforts to use PP that are as safety possible.
35	Ensure that are only used packaging which does not damage the environment and that do not affect the staff.
36	Participate in the plans for the protection of personnel in the event of industrial accidents or natural disasters.
37	Adapt the packaging and PP to launch new products, whether their own or of the competition.
Related to other positions of MoLoBaC	
38	Establish communication with all managers of MoLoBaC, to define the packaging and PP.
39	To make use of the relations of the M&SM and that of External relations Mg, with the final clients, to incorporate the packing that these need.
40	Help to the M&SM to encourage the selling, through the packing, of all the products, especially those that generally present to the consumer under self-service.
41	Contribute with the M&SM so that through the packing there are improved the marketing functions of the organization.
42	To collaborate with the Stores Mg and the HM Mg in the HM of packing those are in the warehouses.
43	Work jointly with the managers of ID and M&S, to design new packaging.
44	Coordinate together the Maintenance general Mg and his subordinates, the maintenance of equipment for PP.
45	Agree with the Storage Mg, the storage conditions of the packing.
46	Know, through the Processing orders Mg the pending orders, to prepare the necessary packaging.
47	Realize together to Mg of forecasts, estimates of the needs of packaging.
48	Participate with the Project Mg on projects that help improve packaging and PP.
49	To coordinate with the IL Mg and his subordinates everything relative to the material of packing that return to the organization for this route. Attending, principally, on a better use.
50	Caring, together the ISIR Mg, the PP are safe for staff and that they comply with safety standards.
51	Supply, packaging personnel safety equipment required, with the help of ISIR Mg and S&E Mg.
52	To adapt the sizes and volumes of the packing to the available spaces for their movement. For it will coordinate with the managers of HM and Layout.
53	Achieve, working jointly with the HM Mg, that packaging in its different phases can be handled with the least difficulty.
54	Have a control together the S&E MG, of the availability of equipment for the process of packaging.
55	Intervene, together the Inventory Mg and their subordinates, in the formulation, approval and implementation of the plan materials inventory on his responsibility, ensuring adequate inventory of materials and equipment for packaging.
56	Prepare, together with the HR Mg, career planning and training of their staff.
57	Ensure, in collaboration with the managers of Quality and Cost, which supplies for packaging and PP are handled at low cost without sacrificing the quality required.

58	To coordinate with the Procure Mg and his subordinates, the acquisition and suitable reception of materials and equipments for the process of packed, as well as of the proper packing.
59	To help to the Expansion Mg in the plans of growth of the organization, through an adaptation of the packing to the future circumstances.
60	To support the Mg of Finance, in the making of the budget of the organization.
61	Maintain constant exchange with the R&D Mg and their subordinates to receive first hand any new information that might arise on packing, worldwide.
62	Review, together with the R&D Mg and his subordinates, all equipment, new materials and new technologies that can help generate improvements in packaging and PP and realize the pertinent incorporations.
63	To guarantee through the packing and PP, that satisfy the needs of the Physical distribution Mg and his subordinates and of the Virtual channel Mg and with it to minimize penalties for late deliveries to the clients.
64	To have, through the Channels Mg, knowledge of the distribution channels, to use the suitable packing.
65	Facilitate to the Picking Mg, the packaging that best suit their needs to complete the orders.
66	Coordinate with the Transport Mg and their subordinates, that packaging are suitable for transporting the products to the end customers, with the fleet and through the available routes.
67	Study with the help of the Ethical & Juridical consultant, the existing legislation on packaging.
68	Care, with the collaboration of the Ethical & Juridical consultant, that packaging and PP also help ensure the security of the organization.
69	Comply, advised by the Ethical & Juridical consultant, with legal regulations requiring primary packaging.
70	Be very careful with the Environmental Mg, for packaging are environmentally benign.
71	Maximize customer service levels through packaging.
Related to MoLoBaICa, LAPDI, MoLETOI and the enterprise logistics in general	
72	Work, so that in the PP, managing flows, particularly those materials, as efficient as possible.
73	Maintain permanent control of flows of materials used to pack.
74	To be a constant supervisor of the flows of information, especially information that may affect the PP.
75	To contribute positively with the monetary flows through the packed.
76	To use the philosophy of MoLoBaICa, to generate indicators, together with other models, who allow him to know the proper performance, that of his subordinates and equipments, materials and machineries used in the PP.
77	To help to improve, through the PP, the tactical performance and especially the operative one of the organization.
78	Getting the PP are made reaffirming the vision, mission and guiding principles of the organization.
79	Take care that the packaging process facilitates operational tasks of the organization.
80	Collaborate on minimizing losses of product and especially of time, through the PP.
81	To support the functions logistics of the organization through the PP.
Related to SCM and the enterprise and its environment as a whole.	
82	Maintain contact and support providers to ensure better supplies for packaging to the organization.
83	Watch for changes in the economy that may affect the demands of certain packaging.
84	Create opportunities for improvement, through packaging and PP, for the organization and SCM.
85	Share the advances in PP with all SC.
86	Ensure that the PP facilitates the work of the remaining elements of the SC.
87	Create PP so as to provide support to other members of the SC.
88	Convert the packaging as an element of added value for the SC.
89	Generate PP, to help the preservation of resources, especially energy.

90	Be aware that the PP does not cause problems in the environment.
91	Being environmentally responsible with the environment through the PP.
92	To create conscience in the whole company and its environment on the importance of the PP.
93	To use the packing and the PP, like a support to the society.

Although the number of functions can grow, here it has tried to present the most fundamental. They are sufficient to analyze the possibilities of the PM of the MoLoBaC, to participate in the generation and knowledge management, in an organization, an aspect which will be discussed in the next chapter.

4. ANALYZE THE GENERATION AND KNOWLEDGE MANAGEMENT THROUGH THE PACKING MANAGER

Especially for reasons of space, as in previous works (Barreto [9]; García, Hernández & Hernández [10,17]; Hernández, García & Hernández [13]; Jeney et al. [15]), the illustration will do of how it is possible to generate and to manage the knowledge of an organization, supported on the functions of the Packing manager (PM), through the tables 2 to 10.

In the first four tables, 2, 3, 4 and 5, it presents the impact of PM in the four fundamental processes of the model of Nonaka, Toyama & Konno [18]: Socialization, Externalization, Combination and Internalization. In the table 6 the relationship of PM with the Ba will be shown and in the last four tables, 7, 8, 9 and 10, will analyze the impact of the PM in the four above mentioned knowledge assets: Experiential, Conceptual, Systemic and Routine.

Table 2 – The Packing manager and the Socialization

SECI **(Socialization)**	
Aspects	Functions that do
Share experiences:	
With his subordinates.	Practically all, emphasizing the functions 01 to 37; 42; 45; 46; 48; 50; 51; 56; 60; 65; 68; 70; 76; 80.
With other positions of MoLoBaC.	Highlight the functions 38 to the 75; 79 to 81; 84.
With external entities.	Especially the functions 82 to 93.
Exchange of information.	All the functions from the 01 to the 93.
Frequent meetings.	MoLoBaC considered routine, by which are not covered explicitly in the functions.

Table 3 – The Packing manager and the Externalization

SECI **(Externalization)**	
Aspects	Functions that do
Crystallizes the knowledge.	They stand out: 01; 02; 05; 07 to 09; 11 to 14; 16 to 18; 21; 23; 25; 39; 52; 61 to 64; 66; 67; 77.
Transformed into explicit the tacit knowledge.	Excel: 03; 06; 08; 09; 11; 13; 14; 17; 18; 21; 23; 52; 64.
Articulated work.	Especially: 04 to 09; 11; 15; 17; 20; 27; 29; 33 to 73; 79 to 82; 84 to 87; 89 to 92.
Forms the basis of new knowledge.	Basically all functions of the 01 to the 93.

Table 4 – The Packing manager and the Combination

SECI **(Combination)**	
Aspects	Functions that do
Systematized knowledge.	Mainly: 01 to 05; 07 to 09; 11; 13; 16 to 18; 21; 24; 25; 27; 32 to 34; 37 to 39; 43; 47; 48; 52; 61 to 63; 67; 74.
Convert explicit knowledge into more explicit knowledge.	Essentially: 01 to 03; 05 to 09; 11; 13; 15; 16; 24; 35; 39; 43; 47; 48; 61 to 63; 67; 74; 85.
Helps to process, combine, edit and convert knowledge into new knowledge.	Primarily: 01 to 13; 15 to 18; 20; 21; 24; 25; 27 to 29; 32 to 35; 37 to 39; 41; 43; 47; 48; 52; 61 to 63; 67; 74; 76; 82; 85.

Table 5 – The Packing manager and the Internalization

SEC**I (Internalization)**	
Aspects	Functions that do
Integrates knowledge.	Basically: 01; 05; 07 to 11; 13; 15; 16; 18; 20; 24; 28; 32; 35; 37 to 72; 76; 81; 82; 85; 87; 89; 93.
Converts explicit knowledge into tacit knowledge.	Principally: 01; 08; 09; 13; 16; 24; 25; 39 to 43; 67; 76; 85.
Spread the new knowledge.	Practically through all functions 01 to 93.

Table 6 – The Packing manager and the Ba

Ba	
Aspects	Functions that do
Offer: The atmosphere. Space. Time. Conditions Space-time.	The managers of the MoLoBaC, in particular the Packing manager, do not generate in explicit form the Ba, nevertheless, in the following functions it is possible to see its presence: 01; 02; 05; 08; 09;13; 15; 16; 20; 22; 24; 29; 34 to 71.

Table 7 – The Packing manager and the Knowledge assets Experimental

Knowledge assets (Experimental)	
Aspects	Functions that do
Emotional and affective.	In practice all the functions. Participate all positions of MoLoBaC and subordinates of the PM.
Tacit knowledge shared and re-built.	Participate, practically all the functions, but it is still proper to each organization.

Table 8 – The Packing manager and the Knowledge assets Conceptual

Knowledge assets (Conceptual)	
Aspects	Functions that do
Images and symbols.	It can consider all the functions.
Explicit knowledge.	Stand out: 01 to 11; 13 to 21; 24; 29; 32; 34; 35; 38 to 41; 45; 47; 56; 59; 61 to 64; 67; 76; 81; 82; 84; 85; 93.
Shared knowledge.	Practically all functions, highlighting the 01 and those between the 38 and the 71.

Table 9 – The Packing manager and the Knowledge assets Systemic

Knowledge assets (Systemic)	
Aspects	Functions that do
Explicit knowledge organized, systematized and legalized.	More visible of the Knowledge assets. Practically all the functions, especially the related to the Ethical & Juridical consultant and predetermined rules: 01, 18; 23; 43; 67 to 70.
Easy to understand and to transmit.	All the functions.

Table 10 – The Packing manager and the Knowledge assets Routine

Knowledge assets (Routine)	
Aspects	Functions that do
Organizational culture.	It is essentially practical. Involved all functions. It is also unique to each organization.
Tacit knowledge that is already implanted, embedded in the daily work of the organization.	

In the tables 2, 3, 4 and 5, it was observed as the PM intervenes directly in each of the four processes that make up the model of Nonaka, Toyama & Konno [18]. In the same way, in the table 6, there is seen the capacity that has the PM, to help to generate the necessary ambience so that the generation and management of the knowledge could happen of natural form. Finally, in the tables 7, 8, 9 and 10, is seen as the functions of PM drive the generation of knowledge assets that can be useful for the organization. Although for reasons of space and not being part of the objective of this work, neither discussion is made about the implementation of these knowledge assets, nor the processes that comprise the SESI, nevertheless, with the reflected in the tables 2 to 10, there can be present some conclusions and recommendations or lines of future investigation.

5. CONCLUSIONS AND FUTURE RESEARCHS

With 93 functions of the Packing manager (PM), showed in the table 1, it is achieved to visualize as each of the processes of the model SECI they could be satisfied making use of them. Also it showed that the PM offers the ambience necessary for the generation and management of the knowledge, what was equally reflected, to find that the functions of the table 1, also facilitated the generation and use of the knowledge assets.

Mentioned these achievements, it can be concluded that there is a model for the study of the generation and knowledge management, that can be used from the business logistics, particularly following the Logistic Model Based on Positions (MoLoBaC) and especially following the functionality of the PM. What at a time allows to affirm that there are many functions that this manager must redeem and that they are intimately related to many aspects of the manufacturing companies, highlighting the legal and marketing aspects. And finally it is possible to conclude that following the model of knowledge management select, the model SECI or spiral model, it is possible to affirm that the PM is a good agent for the generation and knowledge management in the organizations, since through their functions can be activated the Socialization, the Externalization, the Combination and the Internalization, in addition to contributing in with the knowledge assets Experimental, Conceptual, Systemic and Routine and all of them under an environment, Ba, which facilitates it. This activation through the PM achieved, following the spiral proposed by the model, a constant exchange of knowledge of tacit to explicit to tacit and so on indefinitely. This achieved a better use all the knowledge in the organization.

All this allows to recommend, continue to deepen this line of research and continue studying other positions of MoLoBaC, which can also contribute to the generation and knowledge management in the organizations.

6. REFERENCES

[1] De Long, D., Seemann P.: *Confronting conceptual confusion and conflict in knowledge management*, Organizational Dynamics, 29(1)(2000), 33–44.

[2] Madeira, L.M.M., Vick T.E., Nagano M.S.: *Directions of scientific literature in knowledge management from the perspective of their relationships with innovation, information and technology management*, Transinformação, 25(2)(2013), 167–174.

[3] Makhsousi, A., Sadaghiani J., Amiri M.*: Investigating different cultural factors on establishment of knowledge management in educational organization*, Management Science Letters, 3(2)(2013), 581–586.

[4] Malik, K.P., Malik S.: *Value creation role of knowledge management: a developing country perspective*, The Electronic Journal of Knowledge Management, 6(1)(2008), 41–48.

[5] Wagner, Ch.: *Wiki: A technology for conversational knowledge management and group collaboration*, The Communications of the Association for Information Systems, 13(1)(2004), 265–289.

[6] Nzui, C.K.: Information and communication technology and knowledge management at world agroforestry center (ICRAF) in Kenya, Master dissertation, University of Nairobi, Nairobi, Kenya, 2014.

[7] Al-Khouri, A.M.: *Fusing Knowledge Management into the Public Sector: a Review of the Field and the Case of the Emirates Identity Authority*, Journal of Knowledge Management, Economics and Information Technology, 4(3)(2014), 1–89.

[8] Riungu, A.K.: *Effect of knowledge management practices on performance of mobile telephone companies in Kenya*, Master dissertation, University of Nairobi, Nairobi, Kenya, 2015.

[9] Barreto O., E.A.: *Gestión del conocimiento a través del Gerente de Proyectos de un modelo logístico*, Master disertación, Universidad Metropolitana, Caracas, Venezuela, 2012.

[10] García, M.J., Hernández G. G.J., Hernández R. J.G.: *Knowledge management through the Material Handling Manager,* in G. Dukic (Ed.), Proceedings ICIL 2014, University Zagreb: Croatia, 2014, 264–272.

[11] Guerrero M., L.E., Hernández G. G.J., García G. M.J., Hernández R. J.G.: *Indicators and the Picking manager of the Logistic Model Based on positions,* in G. Dukic (Ed.), Proceedings ICIL 2014, University Zagreb: Croatia, 2014, 273–282.

[12] Hernández R., J.G., García G. M.J., Hernández G. G.J.: *Enterprise diagnosis and the Environmental manager of LoMoBaP*, Journal of Global Business and Technology, 12(1)(2016), 60–76.

[13] Hernández R., J.G., García M.J., Hernández G.J.: *Social Aspects of Reverse Logistics and Knowledge Management*, in A. K. Goel & P. Singhal (Ed.), Product Innovation through Knowledge Management and Social Media Strategies. IGI Global: USA, 2016, 65–93.

[14] Hernández G. J.J., García G. M.J., Hernández G. G.J., Hernández R. J.G.: *Fantastic sports and the Research and Development manager of the Logistic Model Based on positions,* in G. Dukic (Ed.), Proceedings ICIL 2014, University Zagreb: Croatia, 2014, 250–257.

[15] Jeney, A.,J. Hernández G., García M.J., Hernández G.J.: *Generation and Knowledge Management System Through the information and networks manager,* in N. Delener (Ed.), GBATA Reading Book 2015, GBATA: USA, 2015, 244–251.

[16] Hernández, J.G., García M.J., Hernández G.J.: *Dynamic knowledge: Diagnosis and Customer Service*, in N. Delener (Ed.), Service Science Research, Strategy, and Innovation: Dynamic Knowledge Management Methods. IGI Global: Hershey, PA USA, 2012, 547–573.

[17] García G., M.J., Hernández G. G.J., Hernández R. J.G.: *A Methodology of The Decision Support Systems applied to other projects of Investigation,* iIn Mehdi K. (Ed.), Encyclopedia of Information Science and Technology, Third Edition, IGI Global: USA, 3(2014), 1978–1990.

[18] Nonaka, I., Toyama R., Konno N.: *SECI, Ba and leadership: A unified model of dynamic knowledge creation*, Long Range Planning, 33(2000), 5–34.

[19] Minhas, S., Juzek C., Berger U.: *Elicitation of Requirements for a Knowledge Management Concept in Decentralized Production Planning*, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 7(9)(2013), 1806–1815.

[20] Shahzad, K., Zia S.A., Aslam M.H., Syed A.R., Bajwa S.U.: *Role of organizational vision and adaptability in knowledge management*, Problems and Perspectives in Management, 11(2)(2013), 24–34.

[21] Cervera F., A.L.: *Envase y Embalaje. La venta silenciosa*, Escuela Superior de Gestión Comercial y Marketing: España, 2003.

[22] Dahlborg, H., Johnsson C.: *Evaluating Packaging Logistics Development at IKEA for Improvements in Product and Packaging Development*, Master dissertation, Lund University, Lund, Sweden, 2006.

[23] Gurgel, F.A.: *Logística Industrial*, Editora Atlas S. A.: Brasil, 2000.

[24] Jernberg, A., Svensson S.: *Improved parts Packaging. A case study performed at Tetra Pak Technical Service AB*, Master dissertation, Lund University, Lund, Sweden, 2006.

[25] Kuvykaite, R., Dovaliene A., Navickiene L.: *Impact of package elements on consumer's purchase decision*, Economics and Management, 14(14) (2009), 441–447.

[26] Saghir M.: *The concept of packaging logistics*, Proceedings of the Fifteenth Annual POMS Conference, Cancun, México, 2004.

[27] Theppituck, T., Watanabe M., Ono K., Paskevicius K.A.: *Investigation of Shelf Ready Packaging Design Solutions*, Working paper, Chiba University, Chiba, Japan, 2012.

[28] Vernuccio, M., Cozzolino A., Michelini L.: *An exploratory study of marketing, logistics, and ethics in packaging innovation*, European Journal of Innovation Management, 13(3)(2010), 333–354.

[29] Hernández R., J., García G. M., Hernández G. G.: *Enterprise Logistics, Indicators and Physical Distribution Manager*, Research in Logistics & Production, 3(1)(2013), 5–20.

AN INTEGRATED MODEL OF STORAGE AND ORDER-PICKING AREA LAYOUT DESIGN

Goran DUKIC[1], Tihomir OPETUK[1], Tone LERHER[2]

[1]University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
Ivana Lucica 5, Zagreb,
Croatia
[2]University of Maribor, Faculty of Logistics
Mariborska cesta 7, Celje,
Slovenia

Abstract:

In many warehouses both storage and order-picking process take place in same physical area. Designing layout of such area using either model for optimal storage area layout or model for optimal picking area layout leads to sub optimization. This paper presents an idea and initial attempt to combine those models into one integrated model, aimed to design optimal physical layout minimizing expected total travel distances of all operations. Presented analysis for different cases provides useful guidelines for designing layout of storage and low-level order picking area.

Keywords:

storage area layout, order-picking area layout, integrated model, warehouse design

1. INTRODUCTION

It is well known that logistics costs have an important influence on the business success of any company. Representing on average around 10% of sales in western companies, costs of logistics operations in industrial systems can play a vital role in determining the competitiveness of a company. The efficiency and effectiveness of logistics of a company are largely determined by design of logistics systems and operations performed in such systems. Warehousing systems are one of them. Since warehouses are in most cases non-avoidable places within the production site of industrial companies, and are also nodes in the distribution network towards final customers, proper warehouse planning and control have drawn full attention in literature [1,2,3]. Warehouse design is unfortunately highly complex task with many trade-offs between conflicting objectives and a large number of feasible designs. In [2] was proposed a structured approach to warehouse decision making, with the strategic, tactical and operational levels. In [3] was proposed a framework of warehouse design and operation, classifying the warehouse design problems as overall structure, sizing and dimensioning, department layout, selection of equipment and operation strategy. Both contributions have a common conclusion that multiple decisions are interrelated and have to be solved simultaneously, while, unfortunately, the majority of papers listed in their literature reviews are focused on the analysis of an isolated problem rather than on the synthesis. This is also concluded in [4]. According to [3], a researcher addressing one decision would require a research infrastructure which would integrate all other decisions, and to properly evaluate the impact of changing one of the design decisions requires estimating changes in the operation of the warehouse.

Those mentioned conclusions were drivers for writing this paper that aims to combine two, in literature addressed isolated problems, into one integrated problem and solution. Namely, those problems are optimal storage area layout problem and optimal order-picking area layout problem (in warehouse design also usually named as aisle configuration problems). Those two most important areas in warehouses already got a lot of attention of researchers regarding solutions (models) of optimal layout design. However, all so far developed models are analyzing storage or order-picking areas isolated one from another, trying to design an optimal layout either regarding expected travel distance for storage/retrieval operations or expected distance of routes in picking operations.

Although there are warehouses with separate storage and order-picking areas (and this approach is valid), in many warehouses there is only one physical area where both storage/retrieval of pallets and order-picking of cases/items take place. One clear example, which is in focus of this paper, is warehouse system of selective pallet racks where higher level rack locations serve as storage (reserve) locations, while lower level locations are picking locations. Such racking system is in the same time a (reserve) storage system and low-level manual order-picking system. Since pallet storage, full pallet picking, replenishment of picking locations and case- (and even item-) picking occur in such systems, the problem stated for this research is: can we find and design an optimal area layout, such that will minimize expected total travel distance (or travel time, or cost of travelling) of all mentioned operations.

In the remainder of this paper Section 2 briefly explains layout design problems that are in focus of this paper, as well as selected models for storage and order-picking area layout design identified as applicable sub-models (parts) of proposed integrated model. Developed integrated model of storage and order-picking area layout is presented in Section 3. Analysis of proposed model's results, applicability and usefulness on several instances is presented in Section 4. Comments on limitations and deficiencies of proposed model and possible ways of further research are given at the end of the paper in Conclusion.

2. STORAGE AND ORDER-PICKING AREA LAYOUT PROBLEM AND MODELS

The layout problem of storage area of conventional warehouses has quite a long history ever since 1960s. In 1980s and 1990s, a lot of attention was given to the layout problems of automated storage/retrieval systems. The layout of conventional warehousing systems with manual order-picking from multiple aisles has been the topic of several papers only in the last 15 years. Recently, some radically new, innovative warehouse layouts, which do not include traditional assumptions, have been proposed in [5]. Despite those new innovative layouts as well as various automated systems available, most warehouses today are still designed as conventional warehouses with traditional storage and order-picking layout. The basic form of such layout is rectangular, with parallel straight aisles. There are two possibilities for changing aisles, at the front and at the rear of the warehouse. These aisles are also straight and meet the main aisles at right angles. One such layout is given in Figure 1 (with symbols explained in section 3).

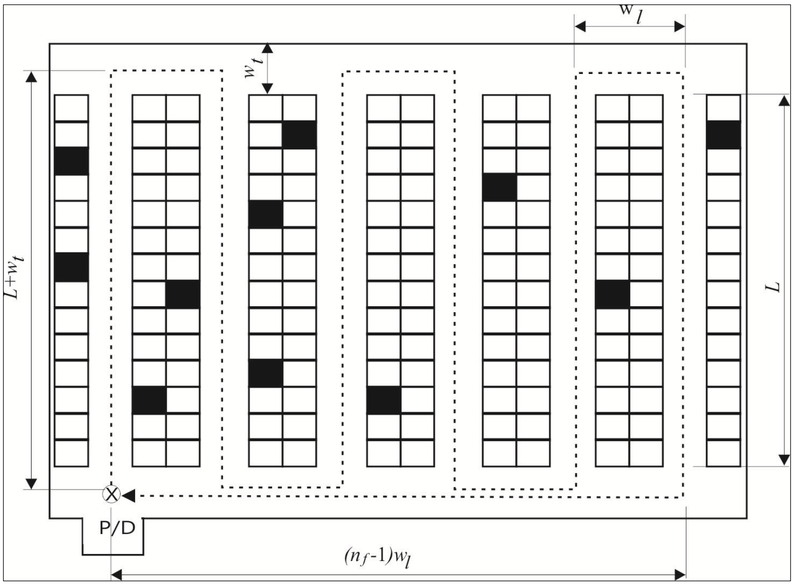


Figure 1 – Basic storage and order-picking area layout

Therefore, the term "a conventional storage area layout" in this paper refers to the layout with unit-load operations (storage and retrieval) in above described layout, while the term "conventional order-picking area layout" refers to the one with manual order-picking operations (case- or item-picking) from pick locations in above described layout. One example, where both storage and order-picking operations occur in the same physical area is the system of selective pallet racks, illustrated in Figure 2. Storage or/and retrieval of unit-loads (full pallets) in presented system would be done either with single commands (one storage or one retrieval per trip) or dual commands (combining one storage and one retrieval per trip). Since for a given required capacity of storage area (number of storage locations) one could design various layouts (altering the number of aisles and the length of aisles), the problem is which layout is optimal regarding the design objective. Design objective could be minimization of cost (investment cost and operational cost), time (operations of storage and retrieval), or simply only expected travel distance (minimizing travel time as most dominant component of total operation time). Most models in literature optimize the layout minimizing the expected travel distance to store/retrieve an item. The theoretical background to warehouse layout can be found in [6] with derived expressions for optimal warehouse designs represented as continuous storage areas both for non-rectangular and rectangular designs. A simple model for optimal storage layout that minimizes the expected travel in the rectangular storage area with parallel aisles assuming random storage and single location of pickup and delivery point (P/D), which might be located in any place along the front aisle or in the corner, was presented in [7]. That model is used as a part of our proposed integrated model in Section 3. Similar idea for optimal storage layout, although in case of dual commands, was used in [8].

Figure 2 – Storage and order-picking system with selective pallet racks

Designing the layout of order-picking area could have even greater influence on the efficiency of warehouse operations. The order-picking process, defined as the process of retrieving items from storage locations in response to a specific customer request, is the most laborious and the most costly activity in a typical warehouse, making up to 55% of the total operating costs of a warehouse [9]. The order-picking operation in illustrated system with Figure 1 consists of visiting several picking locations (marked as black locations) and retrieving cases (or items) in picking route. Efficient order-picking process could be achieved using various operating policies. The fact that about 50% of total order-picking time in conventional warehouses is spent on travelling [9] is the reason that most methods aimed for operational efficiency of order-picking focus on reducing travel times (distances). For a most comprehensive overview of literature regarding the methods in order-picking systems we refer to [10]. The most important for this research are routing methods that determine the picking sequences and routes of travelling, trying to minimize total travel distances. The analysis of routing methods presented in literature has shown a non-negligible influence of the layout on their performances. Therefore, minimized expected travel of picking routes for selected methods could be achieved with optimal layout of order-picking area. Order-picking area layouts that can be found today in the majority of warehouses are the same as for the storage area. A non-linear programming model for optimal order-picking layout is presented in [11]. The model aims at finding the minimum average travel distance expressed as a function of a number of layout variables and parameters (number of aisles, length of aisles, depot location, width of aisles including storage racks, width of a cross-aisle), under defined conditions. The mathematical expressions for the expected route distance for probably most popular routing policy, named S-shape policy, was presented in [12]. This model is also used as a part of our proposed integrated model in Section 3.

3. INTEGRATED STORAGE AND ORDER-PICKING AREA LAYOUT MODEL

As mentioned in introduction, developed storage layout models and order-picking layout models consider two problems independently and minimizing either expected storage/retrieval cycles or picking routes. In presented conventional system with pallet racks both storage/retrieval and order-picking operations occur in the same layout. Additionally, picking locations should be replenished from time to time with goods stored in upper locations (reserve locations). Replenishment was not considered in any of previously mentioned models. Idea of finding such layout that could minimize all relevant travels motivated us toward development of integrated storage and order-picking layout model. However, there is a certain complexity of that problem considering all possible influencing variations and control policies: There are alternatives of possible conventional layouts; Storage and full pallet retrieval operations could be done by single and dual commands; Replenishment operations might be also carried out with single commands or combined with storage and/or retrieval in more complex commands; Various picking policies also have influence on expected routes and therefore resulting optimal layout; Storage policies (slotting) would have impact both on storage/retrieval and picking operations; etc. To explore the proposed idea, most simple model is developed, with aim to investigate applicability and possible usefulness. It considers layout illustrated in Figure 1, with parallel aisles (racks), front and rear aisle, and one P/D location in the corner. Storage, retrieval, replenishment and order-picking operations start and end at P/D location. Storage, retrieval (full pallet picking) and replenishment operations are assumed as single commands regarding travel. Although replenishment cycle of course has 2 operations (retrieval of full pallet from reserve storage location and put away of that full pallet into picking location), it is assumed that reserve location is above picking location so travel for replenishment is equal to a single command. Storage assignment method is assumed random therefore any location is equally likely to be visited for storing, retrieval or replenishment (meaning no using popularity to determine locations for items in front, however storage locations should be above picking locations).

Notation used in models and Figure 1:
L^* – total storage capacity per layer in meters (total length of pallet racks, $L^*=2NL$),
L – length of one pallet rack = length of an aisle [m],
B – width of storage/order-picking area [m],
w_t – width of front and rear aisle [m],
w_l – width of racking segment per one aisle [m],
N – number of aisles,
x – order size (equals the number of visited locations in picking tour),
E_S – expected travel of storage or retrieval cycle [m],
E_R – expected travel of replenishment cycle [m],
E_P – expected travel per picking cycle [m],
n – expected number of visited aisles in picking tour,
n_f – expected furthest aisle in picking tour,
X – expected number of pallets stored in the system in observed time T,
X_1 – expected number of pallets picked (retrieved) as full pallets in observed time T,
X_2 – expected number of pallets used for replenishment of picking locations in observed time T,
p_1 – fraction of stored pallets picked as full pallets,
p_2 – fraction of stored pallets used to replenish picking locations,
Y – expected number of picking cycles in observed time T,
k – factor defining number of replenishment cycles in relation with number of picking cycles (equals the size of the order picked in one tour in relation to the full size of the stored pallet),
E_T – expected total travelled distance by forklifts and picking trucks in observed time T [m],
$E_{T/X}$ – expected total travelled distance per one stored pallet [m].

Using storage layout models presented in literature, expected travel to storage location (and back from storage location to P/D point) for storage/retrieval in single command can be expressed as (1).

$$E_S = \frac{L^*}{4 \cdot N} + \frac{w_t}{2} + \frac{(N-1) \cdot w_l}{2} \qquad (1)$$

As already explained, for the sake of simplicity expected travel to and from location in replenishment cycle could be represented in the same way as single command, with the same equation as expected storage/retrieval travel (2).

$$E_R = \frac{L^*}{4 \cdot N} + \frac{w_t}{2} + \frac{(N-1) \cdot w_l}{2} \tag{2}$$

For order-picking we assume most used in practice routing heuristics, S-shape policy. With the S-shape routing policy, any aisle containing at least one item is traversed through the entire length. Aisles where nothing has to be picked are skipped. Aisles are visited in sequential manner. Figure 1 illustrates one example of a picking route using S-shape policy. In [12] authors recognized this problem similar to occupancy problem, and derived expressions for expected number of visited aisles and expected furthest visited aisle, as (3), (4):

$$n = N \cdot \left[1 - \left(1 - \frac{1}{N}\right)^x\right] \tag{3}$$

$$n_f = N - \sum_{i=1}^{N-1} \left(\frac{i}{N}\right)^x \tag{4}$$

where x is the size of the order that equals the number of visited picking locations. Expected picking travel per route can be then expressed as (5):

$$E_P = n \cdot \left(\frac{L^*}{2N} + w_t\right) + 2 \cdot \left(n_f - 1\right) \cdot w_l \tag{5}$$

In one particular system there might be different number of storage, full pallet picking (retrieval), replenishment and picking cycles per observed time T. Let's assume X number of pallets stored in the system. Some number of pallets might be retrieved as full pallets (X_1) while the rest (X_2) will be used for replenishment of picking locations. The number of picked (retrieved) full pallets in relation with stored pallets is represented by ratio p_1 as $p_1 = X_1/X$. Number of pallets used for replenishment of picking locations in relation with stored pallets is accordingly represented by ratio p_2 as $p_2 = X_2/X$. The cases or items (requested by customers) will be retrieved from pallets used for replenishment by order-picker in picking cycles. In case of many small orders, number of picking trips might be significantly larger than number of replenishments. In case of larger order sizes picker might pick approximately full mixed pallet per route and number of trips could be similar to the number of replenishments. In cases where picker is using picking truck with double sized forks (carrying two pallets) number of picking cycles could be even smaller than number of replenishments. To address all those possible situations factor k is introduced in proposed model, in order to relate number of picking cycles Y to a number of replenishments X_2 as $k = Y/X_2$. Factor k therefore could be considered also as the fraction of the full pallet picked in one picking tour. In observed time T with X number of full pallets entering the system for storage, X_1 number of retrieved pallets as full pallet picking, X_2 number of replenishments of picking locations and Y number of picking cycles, expected total travel distance by forklifts and picking trucks could be expressed as (6):

$$E_T = 2 \cdot X \cdot E_S + 2 \cdot X_1 \cdot E_S + 2 \cdot X_{2.} \cdot E_R + Y \cdot E_P \tag{6}$$

Using equations from (1) to (5), for p_1, p_2 and Y, and then dividing total travel distance with X, expected total travel distance per stored pallet could be finally expressed as

$$E_{T/X} = 4 \cdot \left(\frac{L^*}{4 \cdot N} + \frac{w_t}{2} + \frac{(N-1) \cdot w_t}{2} \right) + \\ + \frac{(1-p_1)}{k} \cdot \left\{ N \cdot \left[1 - \left(1 - \frac{1}{N} \right)^x \right] \cdot \left(\frac{L^*}{2N} + w_t \right) + 2 \cdot \left[N - \sum_{i=1}^{N-1} \left(\frac{i}{N} \right)^x - 1 \right] \cdot w_t \right\} \tag{7}$$

Being a function of number of aisles N for a given set of parameters L^*, w_t, w_l, x, k and p_1, minimal expected total travel distance per stored pallet will be achieved with optimal number of aisles N_{opt}.

4. ANALYSIS

Model was analyzed on three different storage size instances (namely small, medium and large layout, with $L^* = 300$, 600, and 900 meters respectively), for different order sizes for picking routes ($x = 5$, 10, 20, and 40) and structure of operations (numbers of different types of cycles represented by values of k and p_1). Varying the number of aisles, sub-models and integrated model were used to calculate expected travel distances for storage/replenishment operations, expected travel distance of picking routes and expected total travelled distance per stored pallet. Values for w_t and w_l were constant, 3 and 5.2 meters respectively. Due to the limited size of the paper, results for only one layout size ($L^* = 600$) are presented for 3 typical scenarios.

4.1. Structure of operations with equal number of order-picking cycles and storage cycles

Table 1 presents resulting values (minimal travel distances are highlighted) assuming all stored pallets are used for replenishment (in other words no full-pallet picking, $p_1 = 0$) and same number of order-picking cycles as storage/replenishment cycles (picking results in full size mix pallets, $k = 1$).

It is obvious from results that optimal layout for storage/replenishment with single command travels do not correspond with optimal layout for order-picking with multiple commands (using S-shape routing policy). Optimal order-picking area layout tends to be with just 2 aisles for “higher density of locations” (lower average distance between locations), which are situations in smaller warehouses and larger orders (higher number of locations to be visited), while in opposite situations optimal order-picking area layouts are often with higher number of aisles compared to the optimal storage area. Obtained results show that obtained minimum value with integrated models is different than minimums for separate optimization of storage and picking layouts. However the differences measured are less than 5% (calculated using values for $E_{T/X}$ in columns with marked minimums).

Table 1 – Expected values of traveling distances for storage/replenishment cycle, picking cycle and total travel per stored pallet (scenario one)

N	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
E_S	81.7	59.3	49.4	44.5	42.1	41.1	41.05	41.6	42.5	43.7	45.2	46.8	48.6	50.5
x=5														
E_P	306.5	287.7	266.4	249.0	236.3	227.3	221.4	217.9	216.2	215.0	217.0	218.9	221.7	225.2
$E_{T/X}$	633.3	524.9	464.0	427.1	404.7	391.8	385.6	384.1	386.2	390.9	397.8	406.3	416.2	427.2
x=10														
E_P	316.1	324.3	325.0	321.6	316.8	312.1	308.1	305.2	303.4	302.6	302.8	303.8	305.6	308.0
$E_{T/X}$	642.9	561.5	522.6	499.6	485.2	476.6	472.3	471.5	473.4	477.6	483.6	491.1	500.0	510.0
x=20														
E_P	316.4	329.7	342.2	352.8	361.4	368.2	373.6	378.1	382.1	385.7	389.3	392.9	396.6	400.4
$E_{T/X}$	643.2	566.9	539.8	530.8	529.8	532.7	537.8	544.4	552.1	560.7	570.1	580.2	591.0	602.4
x=40														
E_P	316.4	329.8	343.2	356.6	369.8	382.7	395.2	407.2	418.6	429.4	439.7	449.6	459.0	468.1
$E_{T/X}$	643.2	567.0	540.8	534.6	538.2	547.2	559.4	573.4	588.6	604.4	620.5	636.9	653.5	670.1

4.2. Structure of operations with greater number of storage cycles than order-picking cycles

Situation where there are less order-picking cycles than storage cycles might happen where substantial number of stored pallets is picked as full pallets (pallet picking), which is modelled in analyzed situations with p_I=0.5 (therefore half of the stored pallets is picked as full pallets, half is used to replenish picking locations). Less order-picking cycles than storage cycles might also happen when forklift with double size forks is used for picking, resulting in 2 mixed pallets per picking cycle. This is modelled in analyzed situations with $k = 2$. In this case both scenarios explained above are assumed to take place (therefore there are four times more storage cycles than order-picking cycles). Results are presented in Table 2. Being unlikely that smaller order sizes could result in 2 formed full size mix pallets, only larger orders ($x = 20$ and $x = 40$) were considered.

Table 2 – Expected values of traveling distances for storage/replenishment cycle, picking cycle and total travel per stored pallet (scenario two)

N	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
E_S	81.7	59.3	49.4	44.5	42.1	41.1	41.05	41.6	42.5	43.7	45.2	46.8	48.6	50.5
x=20														
E_P	316.4	329.7	342.2	352.8	361.4	368.2	373.6	378.1	382.1	385.7	389.3	392.9	396.6	400.4
$E_{T/X}$	405.9	319.6	283.1	266.2	258.8	256.6	257.6	260.8	265.5	271.4	278.1	285.6	293.6	302.1
x=40														
E_P	316.4	329.8	343.2	356.6	369.8	382.7	395.2	407.2	418.6	429.4	439.7	449.6	459.0	468.1
$E_{T/X}$	405.9	319.7	283.4	267.1	260.8	260.2	263.0	268.1	274.6	282.3	290.7	299.7	309.2	319.0

Less number of picking cycles reduces influence of optimal order-picking area layout on total result. Optimal layout obtained with integrated model is similar to the optimal layout for just storage/replenishment operations, with differences in total travel under 1%. However, please note that optimizing layout using integrated model instead of optimizing it just for order-picking operations results in almost 30% reduction of total travel.

4.3. Structure of operations with greater number of order-picking cycles than storage cycles

There is also possible to have many smaller orders in warehouse, with very intense order-picking. In this case number of order-picking cycles would be much greater compared to the number of storage and replenishment cycles. This situation is modelled with assumptions that there is no full pallet picking ($p_1 = 0$) and that amount of goods on replenished pallet will be picked in 5 order-picking cycles (therefore $k = 0.2$). Results are presented in Table 3, while this time larger orders are skipped being more likely that smaller order sizes ($x = 5$ and $x = 10$) correspond to this situation.

Table 3 – Expected values of traveling distances for storage/replenishment cycle, picking cycle and total travel per stored pallet (scenario three)

N	2	3	4	5	6	7	8	9	10	11	12	13	14	15
E_S	81.7	59.3	49.4	44.5	42.1	41.1	41.05	41.6	42.5	43.7	45.2	46.8	48.6	50.5
x=5														
E_P	306.5	287.7	266.4	249.0	236.3	227.3	221.4	217.9	216.2	215.0	217.0	218.9	221.7	225.2
$E_{T/X}$	1859.4	1675.7	1529.4	1423.3	1349.8	1301.2	1271.3	1255.6	1250.9	1254.8	1265.7	1282.1	1303.1	1327.8
x=10														
E_P	316.1	324.3	325.0	321.6	316.8	312.1	308.1	305.2	303.4	302.6	302.8	303.8	305.6	308.0
$E_{T/X}$	1907.3	1858.5	1822.8	1786.0	1752.3	1724.8	1704.9	1692.5	1687.1	1688.1	1694.7	1706.3	1727.2	1741.9

In this case optimal layout resulting from integrated model is closer to the layout optimized for just picking operations, which is expected. Due to the fact that there are small order sizes (greater distance between picking locations), optimal number of aisles tends to be higher compared to the optimal number of aisles from storage layout model. However, in this case optimizing layout using integrated model instead of picking area layout model would result again in very small reduction of total travel. Even in comparison with design based on optimal storage layout, reductions obtained using integrated model are only about 2.5%.

5. CONCLUSION

From theoretical point of view, analysis of proposed integrated model of optimal storage and order-picking area layout confirms correctness of the idea that it is possible to find optimal layout of storage and order-picking area where storage, replenishment and order-picking operations are taking place. Such layout will result in minimized expected total travel, although reductions that could be achieved are not high. From the practical point of view, based on presented results designers are able to think about "adjusting" solution according to the expected composition of the processes. With domination of full pallet picking operations and/or larger picking orders, layout could be designed closer to the optimal storage layout. With more intense order-picking process expected, layout could be designed closer to the optimal picking area layout.

Of course presented integrated model has several limitations and deficiencies. First of all, only single commands for storage and full pallet picking are assumed. Those two operations might be combined in one dual command cycle, reducing average travel per operation and having influence on optimal storage layout. Location of reserve pallet for replenishment was assumed above picking location, which does not have to be a case in real warehouses and it is then hard to follow random storage policy. Proposed model also assumed S-shape routing method for generating picking routes. For other heuristics or optimal routing one would need different models of expected picking travel. Another limitation is assumed random storage, while in practice dedicated or class-based storage could be applied. Those assignment strategies would affect both average travel distances for storage and order-picking, however they are very difficult to model analytically. Possible congestion also might affect final decision. Congestion increases total time (not distance) and layouts with more aisles are expected to result in less congestion than layouts with smaller number of aisles.

Some limitations of proposed integrated model are also inherited from previously developed sub-models. In practice we will have orders with different size. Averaging order size not necessarily results in the same average travel. Both storage and order-picking model assume start/end location (P/D point) in the corner of the layout. This point might be located anywhere along front aisle or on different locations, changing analytical expressions in the proposed model. Even further, warehouses using WMS with wireless communication might issue tasks to available forklift drivers without the need to travel to the assumed starting position. Another assumption inherited from used sub-models is basic layout with rectangular shape and only two possibilities for changing aisles, at the front and at the rear of the warehouse. Adding additional cross-aisles might reduce both dual command travel in storage/retrieval operations and total route distances of order-picking cycles. However modelling these situations analytically is again very difficult. Assumed one fixed start/end point also doesn’t have to be a case for plenty warehouses. Storage area might be connected with receiving area (and many docks) in a way that it is possible to enter it on different places, while start/end point for order-picking operations could be on completely different place (for instance near sorting/accumulation/packing area or shipping area).

Nevertheless listed limitations and deficiencies, results from presented model might serve to warehouse designers as a guidelines how to design storage and order-picking layout trying to minimize expected total travel distance, leading to the more productive and efficient solutions of storage and order-picking area layouts.

Further research might go into several directions. Limitations and deficiencies of proposed model might be reduced with developing analytical expressions for more complex model. To analyze influence of different parameters (different initial assumptions) that cannot be expressed analytically, simulation could be used. Simulation experiments could be also used to verify proposed formula, taking into account stochastic nature of some parameters as well.

6. REFERENCES

[1] Van den Berg, J.P.: *A literature Survey on Planning and Control of Warehousing Systems*, IIE Transactions 31(1999), 751–762. doi: 10.1023/A:1007606228790.

[2] Rouwenhorst, B., Reuter B., Stockrahm V., Van Houtum G. J., Mantel R. J., Zijm W.H.M.: *Warehouse Design and Control: Framework and Literature Review*, European Journal of Operational Research 122(3)(2000), 515–533. doi:10.1016/S0377-2217(99)00020-X.

[3] Gu J., Goetschalckx M., McGinnis M.: *Research on Warehouse Design and Performance Evaluation: A Comprehensive Review*, European Journal of Operational Research 203(3)(2010), 539–549. doi:10.1016/j.ejor.2009.07.031.

[4] Dukic, G., Opetuk T.: *Warehouse Layouts*. In: *Warehousing in the Global Supply Chain: Advanced Models, Tools and Applications for Storage Systems*, R. Manzini (Ed.), 3-1–3-15, Springer Verlag, New York 2012.

[5] Gue K. R., Meller, R.D.: *Aisle Configurations for Unit-Load Warehouses*, IIE Transactions 41(2009) 3, 171-182. doi: 10.1080/07408170802112726.

[6] Francis R.L., White J.A.: *Facility Layout and Location: an Analytical Approach*, Prentice-Hall, New Jersey 1974.

[7] Bauer P.: *Planung und Auslegung von Palettenlagern*, Springer Verlag, Berlin, 1985.

[8] Pohl, L.M., Meller R.D., Gue K.R.: *An Analysis of Dual Command Operations in Common Warehouse Designs*, Transportation Research Part E 45(3)(2009), 367–379. doi:10.1016/j.tre.2008.09.010.

[9] Tompkins J.A., White J.A., Bozer Y.A., Frazelle E.H., Tanchoco J.M.A., Trevino J.: *Facilities Planning* 2nd ed., John Wiley & Sons, New York 1996.

[10] De Koster, R., Le-Duc, T., Roodbergen, K.J.: *Design and Control of Warehouse Order-picking: A Literature Review*, European Journal of Operational Research 182(2)(2007), 481–501. doi:10.1016/j.ejor.2006.07.009.

[11] Roodbergen, K.J.: *Layout and Routing Methods for Warehouses*, Rotterdam, ERIM, 2001.

[12] Chew, E.P., Tang L.C.: *Travel Time Analysis for General Item Location Assignment in a Rectangular Warehouse*, European Journal of Operational Research 112(3)(1999), 582–597. doi:10.1016/S0377-2217(97)00416-5.

FLEXIBILITY OF DELIVERIES CRITERIA CONNECTED WITH THE COMPETITIVENESS TRANSPORT COMPANIES

Teresa GAJEWSKA[1], Elżbieta WYRAZ[1]

[1]Cracow University of Technology, Faculty of Mechanical Engineering,
Division of Logistics Systems
Jana Pawła II 37, 31-864 Kraków,
Poland

Abstract:

Flexibility of deliveries is important criteria for logistics providers and their customers. It is especially important in competitive market of road transportation of refrigerated cargo which requires special care during delivery. Therefore, the purpose of this paper is proposal flexibility of deliveries models based on the opinion logistics services purchasers as well as logistics services providers. Further proposed the main factors connected with flexibility approach in logistics services, that have been assessed surveyed. The postulates achieved based on the current scientific literature and empirical cases. The paper provides new knowledge in the field of new factors connected with flexibility of deliveries and enables to understand how proposed factors influencing on competitiveness of transport companies.

Keywords:

flexibility of deliveries, refrigerated transport, logistics provider, logistic services, customers

1. INTRODUCTION

Globalization has led to a strengthening of global competition and, as Yang, Marlow, and Lu (2009) observe, has forced logistics service providers to rethink their business service processes in order to better satisfy customers' needs. The increased competitive pressure also forces logistics customers to constantly optimize their business processes and costs, for example, by improving their production systems [1]. Consequently, flexibility has become a critical success factor in the logistics industry and logistics service providers have started to offer new logistics concepts that involve high frequency deliveries [1,2].

Currently, the logistics services market is highly competitive which should mean reduced prices and improved service quality [4]. The supply of logistics services has been developing dynamically over the past dozen or so years. This is due mainly to a growing demand for transport services, including the storage of goods as well as the related formal and legal arrangements [5].

Competitiveness plays an important role in shaping the position of companies in the market. It is a feature that should be taken into account to determine the process of formulating the strategy of enterprise development [6–8].

This paper investigates the problem connected with gain competitive advantage of companies. Flexibility of deliveries is one of the most important criteria for logistics providers as well as their customers. Service flexibility allows it develop new services incorporating new ideas which customers may find attractive [9,10]. Logistics services are increasingly growing in importance in the global economy. It is especially important in competitive market of road transportation of refrigerated cargo which requires special care during delivery. The contributions of this paper include:

- proposal main factors connected with flexibility approach in logistics services,
- evaluation of the importance proposal factors,
- propose a hierarchy of importance of the criteria for the selection of logistics services in the opinion of customers,
- proposal of the flexibility of deliveries model in order to gain competitive advantage of logistics service providers, and sensitivity analysis proposal model.

2. MATERIAL AND METHODOLOGY OF RESEARCH

Literature analysis, interviews, and interviews with both groups of experts in the field of logistics and service as well as with service logistics services has been made. On this basis, a survey to assess the level of quality of road transport refrigeration has been developed. The scope of the survey included, among others an assessment of the factors with a flexible approach to the provision of logistics services.

The paper presented the results of a survey in the evaluation of the factors determining the elasticity of supply companies in the area of road transport refrigeration. Research conducted in 2012 have nationwide coverage and quantitative feature. The methodology of research was carried out in two stages. In the first stage of the research we collected 269 questionnaires received by mail and through a background survey with customers using logistics services road refrigerated delivery. The second stage consisted on research sample of 46 companies providing logistics services in the field of road transport refrigeration. The study adopted the companies operating in the area: national specialist road transport, national and international specialist road transport, domestic and international road transport and national specialist transportation and distribution in the field of frozen products. Responses of the respondents were given by using a five point Likert scale (1 to 5), wherein 5 – the maximum value.

To study the quality of service used statistical quantitative methods. As a result, achieved a set of variables (features) of the examined phenomenon. In order to determine the validity of the selection criteria of logistics services used Wilcoxon test. This test allows to verify the null hypothesis (equality of each group of criteria in order of importance, or lack of significant difference between the analyzed groups).

3. COMPETITIVENESS OF TRANSPORT COMPANIES

3.1. Flexibility of deliveries model in the opinion of purchasers of logistics services

In the study analyzed 19 criteria that can significantly to influence for the selection of logistics services, from published in literature m.in. in Special Report of Logistics Operator of the Year 2011 as well as A. Jezierski and among others H. Brdulak [11–13]. Among them were the criterion flexibility of deliveries with 4.10 grade point average of importance. Set of assessments the importance criteria for the selection of logistics services in the opinion of logistics service purchasers as well as p-value as a result of the Wilcoxon signed-rank test presented in Table 1.

An important criterion for the correctness of the choice of the service provider is flexible deliveries, as evidenced by the third level of importance among the six selected levels (Table 1). Given in Table 1, p-values are the result of the Wilcoxon test verifying the null hypothesis.

The value of the test below 0.05 means that the validity of these criteria the selection of logistics services in the field of refrigerated delivery services differ significantly from each other.

The data given in Table 1 allow you to specify how many levels of validity has created a hierarchy. On the basis of statistical inference noted six levels of the validity of the selection criteria of logistics services in the field of transport refrigeration among which included items affecting the quality of service criteria. These levels are the following:

1. timeliness of deliveries (y_1),
2. faultlessness of deliveries (y_2), promptness of deliveries (y_3), security of deliveries (y_4),
3. frequency of deliveries (y_5), circulation of information on the state of deliveries (y_6), technical infrastructure (y_7), completeness of deliveries (y_8), experience and credibility (y_9), price (y_{10}), **flexibility of deliveries (y_{11})**,
4. service availability (y_{12}), potential executive (y_{13}), complexity of services (y_{14}),
5. computerization (y_{15}), response time to inquiry (y_{16}), innovativeness (y_{17}),
6. geographical scope of deliveries (y_{18}), disputes and complaints (y_{19}).

Values of grade point average of importance presented in Table 1 are a result of the average opinion of logistics service purchasers (269 questionnaires) in the field of the level importance of the criteria for the selection of logistics services. The scale of the evaluations were: 0 – lack of the importance, 1 – very low, 2 – low, 3 – average, 4 – high and 5 – very high the level of the importance.

Table 1 – Hierarchy of importance of the criteria for the selection of logistics services in the opinion of purchasers of logistics services

Grade point average of importance (pt.)	4.72	4.63	4.37	4.27	4.24	4.13	4.11	4.1	4.04	4.01	4	3.96	3.91	3.9	3.88	3.74	3.74	3.72	3.57
Criteria for the selection of logistics services	Timeliness of deliveries	Faultlessness of deliveries	Promptness of deliveries	Security of deliveries	Experience and credibility	Technical infrastructure	Completeness of deliveries	**Flexibility of deliveries**	Circulation of information	Service availability	Response time to inquiry	Disputes and complaints	Frequency of deliveries	Geographical scope of deliveries	Complexity of services	Price	Computerization	Potential executive	Innovativeness
Timeliness of deliveries	1	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Faultlessness of deliveries	0.058	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Promptness of deliveries	0	0	1	0.07	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Security of deliveries	0	0	0.07	1	0.86	0.01	0.03	0	0	0	0	0	0	0	0	0	0	0	0
Experience and credibility	0	0	0.03	0.86	1	0.06	0.09	0	0	0	0	0	0	0	0	0	0	0	0

Technical infrastructure	0	0	0	0.01	0.06	1	0.95	0.47	0.1	0.01	0.03	0.01	0.01	0	0	0	0	0	0
Completeness of deliveries	0	0	0	0.03	0.09	0.95	1	0.68	0.23	0.05	0.07	0.01	0	0	0	0	0	0	0
Flexibility of deliveries	0	0	0	0	0	0.47	0.68	1	0.32	0.12	0.09	0.03	0.01	0	0	0	0	0	0
Circulation of information	0	0	0	0	0	0.1	0.23	0.32	1	0.78	0.61	0.22	0.1	0.01	0.05	0	0	0	0
Service availability	0	0	0	0	0	0.01	0.05	0.12	0.78	1	0.69	0.39	0.31	0.07	0.07	0	0	0	0
Response time to inquiry	0	0	0	0	0	0.03	0.07	0.09	0.61	0.69	1	0.4	0.35	0.23	0.1	0	0	0	0
Disputes and complaints	0	0	0	0	0	0.01	0.01	0.03	0.22	0.39	0.4	1	0.48	0.25	0.3	0.01	0	0	0
Frequency of deliveries	0	0	0	0	0	0.01	0	0.01	0.1	0.31	0.35	0.48	1	0.56	0.88	0.02	0.02	0.01	0
Geographical scope of deliveries	0	0	0	0	0	0	0	0	0.01	0.07	0.23	0.25	0.56	1	0.83	0.06	0.02	0	0
Complexity of services	0	0	0	0	0	0	0	0	0.05	0.07	0.1	0.3	0.88	0.83	1	0.06	0.04	0.01	0
Price	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.06	0.06	1	0.68	0.49	0.02
Computerization	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.04	0.68	1	0.68	0
Potential executive	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0.01	0.49	0.68	1	0.01
Innovativeness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Accordingly, the flexible delivery may be understood as a flexible approach of logistics, dependent on four factors. This approach in the literature interprets D. Kisperska-Moron and S. Krzyżaniak [14]. Therefore, representatives of purchasers of logistics services were asked about the importance of these factors. The results obtained are shown in Table 2.

Grade point average of importance which was shown in Table 1 is arithmetic mean of values evaluation in the opinion purchasers of logistics services.

On the basis of the declaration of the respondents stated that the most important factors associated with a flexible approach to the provision of logistics services in the field of refrigerated delivery services (indication of above 76%) are: fast delivery in the event of unforeseen needs and the ability to customize a specific day / time range of delivery. Considering the percentage indications found that the factor of high and very high validity in the opinion of more than 71% of the respondents was to adjust the size and frequency of deliveries to the seasonality of sales of the product. But for more than 62% of the respondents to adjust the size and frequency of supply to fluctuations in demand was a factor of high and very high importance.

Flexibility of supply as a resultant of the four parameters assessed by representatives of businesses (purchasers of logistics services) can be represented in the same way as in the previous step assessed from the point of view of representatives of the providers of logistics services in the field of refrigerated delivery services.

Table 2 – Evaluation of the importance features connected with flexibility approach in the opinion purchasers of logistics services (source: own research)

Features connected with flexibility approach		Feature with middle (3 pt.) high (4 pt.) and very high importance (5 pt.) (% of indications)	Grade point average of importance (pt.)
Fast delivery in the event of unforeseen needs	a_1	76.95	4.13
The ability to customize a specific day / time range of delivery	a_2	76.21	3.99
Adjusting the size and frequency of deliveries to the seasonality of sales of the product	a_3	71.3	3.81
Adjusting the size and frequency of deliveries to the seasonality of fluctuations in demand	a_4	62.83	3.66

The flexibility of supply can be written as a system of different importance due to the level of significance. In contrast to the assessments of validity provided by the enterprise (purchasers of logistics services) in this case, the vast majority of ratings granted the validity of individual factors are 3, 4 and 5 points for all groups. Therefore, as a model coefficients can be taken simply percentages indications ratings 3, 4 and 5 points. In connection with which, in the present case for the importance of each factor flexibility of supply are as follows:
$a_1 = 0.77$ for fast delivery in the event of unforeseen needs,
$a_2 = 0.76$ for the ability to customize a specific day / time range of delivery,
$a_3 = 0.71$ for adjusting the size and frequency of deliveries to the seasonality of sales of the product,
$a_4 = 0.63$ for adjusting the size and frequency of deliveries to the seasonality of fluctuations in demand.

Hence the assessment model flexibility of supply can be written as a weighted average, calculated taking into account factors:

Objective function: global evaluation of the importance flexibility of deliveries in company

$$E(\overline{x}_i) = \frac{\sum_{i=1}^{4} a_i x_i}{\sum_{i=1}^{4} a_i} \rightarrow \max \qquad (1)$$

where:
$E(\overline{x}_i)$ – flexibility of deliveries, $E(\overline{x}_i) \in [0,5]$
a_i – weight (if the coefficient is greater than the decisive feature the level of flexibility of deliveries is more important), $a_i \in [0,1]$
x_i – decisions variable, evaluation from respondent (representativeness of purchasers logistics services) for the group i, values of the evaluation, $x_i \in \{0,1,2,3,4,5\}$.

Existing restrictions can be written in equation form:

$$g_j(x_i) \le c_j, j = 1,...,n \tag{2}$$

Examples of restricting the flexibility of supplies in the enterprise:
1. deliveries except Sunday,
2. the frequency of the supply min. 100 pcs. loading,
3. the supply of seasonal products implemented only on weekdays.

Proposed flexibility of deliveries model was developed on the basis of assessments of the research survey from 269 representativeness of companies using the logistics services in the field of road refrigerated transport. Result of the model is maximizing global assessment connected with the flexibility of deliveries in companies. The assessment is in range [0,5]. This model it includes 4 levels of the importance features of flexibility deliveries (Table 2).

3.2. Flexibility of deliveries model in opinion of logistics service providers

The flexibility of supply as an important criterion for the correctness of the choice of the service provider may be understood as a flexible approach of logistics and dependent on four factors. The results obtained in the opinion of representatives of logistics services providers are presented in table 3.

Table 3 – Evaluation of the importance features connected with flexibility approach to logistics services providers (Source: own research).

Features connected with flexibility approach		Feature with high (4pt.) and very high importance (5 pt.) (% of indications)	Grade point average of importance (pt.)
The ability to customize a specific day / time range of delivery	a_1	100	4.52
Adjusting the size and frequency of supply to fluctuations in demand (daily, weekly, monthly)	a_2	93	4.44
Fast delivery in the event of unforeseen needs (lack of goods on a sudden increase in demand)	a_3	86	4.44
Adjusting the size and frequency of deliveries to the seasonality of sales of the product	a_4	93	4.28

Service providers declared that in their opinion for customers during the provision of logistic services the most important factor associated with a flexible approach to the provision of logistic services is the ability to customize a specific day / time range of delivery (100% of responses). For about 93% of the respondents factors of high and very high validity were: adjusting the size and frequency of supply to fluctuations in demand (daily, weekly, monthly), as well as the seasonality of sales of the product. But for 86% of the companies providing logistic services in the transport refrigeration fast delivery in the event of unforeseen needs (lack of goods on a sudden increase in demand) a factor of high and very high importance.

Flexibility of supply as a resultant of the four parameters can be written as a system of similar importance because of the significance. The vast majority of ratings granted the validity of each factor is 4, and 5 points for all groups. Therefore, as a model coefficients can be taken simply percentages indicated ratings 4 and 5 points.

Thus:
$a_1 = 1$ for the ability to customize a specific day / time range of delivery,
$a_2 = 0.93$ for adjusting the size and frequency of supply to fluctuations in demand (daily, weekly, monthly),
$a_3 = 0.86$ for fast delivery in the event of unforeseen needs,
$a_4 = 0.93$ for adjusting the size and frequency of deliveries to the seasonality of sales of the product.

So the assessment model flexible deliveries may be understood as in the previous model (1) as a importance average using the calculated ratios:

Objective function: global evaluation of the importance flexibility of deliveries in company

$$E(\overline{x}_i) = \frac{\sum_{i=1}^{4} a_i x_i}{\sum_{i=1}^{4} a_i} \rightarrow \max \qquad (3)$$

where:
$E(\overline{x}_i)$ – flexibility of deliveries, $E(\overline{x}_i) \in [0,5]$
a_i – coefficients (the coefficient is greater than the decisive feature the level of flexibility of deliveries is more important), $a_i \in [0,1]$
x_i – evaluation from respondent for the group i, values of the evaluation $x_i \in \{0,1,2,3,4,5\}$.

Similarly as in the previous case, the existing restrictions can be saved:

$$g_j(x_i) \le c_j,\ j = 1,\ldots,n \qquad (4)$$

With the same restricting the flexibility like in the previous case.

The calculation process of the proposed model (3) is the same as in the previous stage. In this case also it includes 4 levels of the importance features connected with flexibility approach (table 3).

In Figure 1 was shown a comparative analysis of the average ratings of the factors flexibility of supply.

Analyzing the results of the survey in the field of the importance factors of flexibility of deliveries it was found that in the opinion logistics service customers assessment were slightly lower than logistics service providers, what it seems understandable. According to the representativeness of logistics service customers 3 of the 4 analyzed factors of the flexibility of deliveries received the importance of less than 4 pts., where 3 means average of the importance of factor, and 4 – high the importance of the factor. Only fast delivery in the event of unforeseen needs they are the high of the importance for the customers using logistics services in the field of refrigerated delivery services. In turn the opinion of logistics service providers the importance all of the four factors assess high or very high.

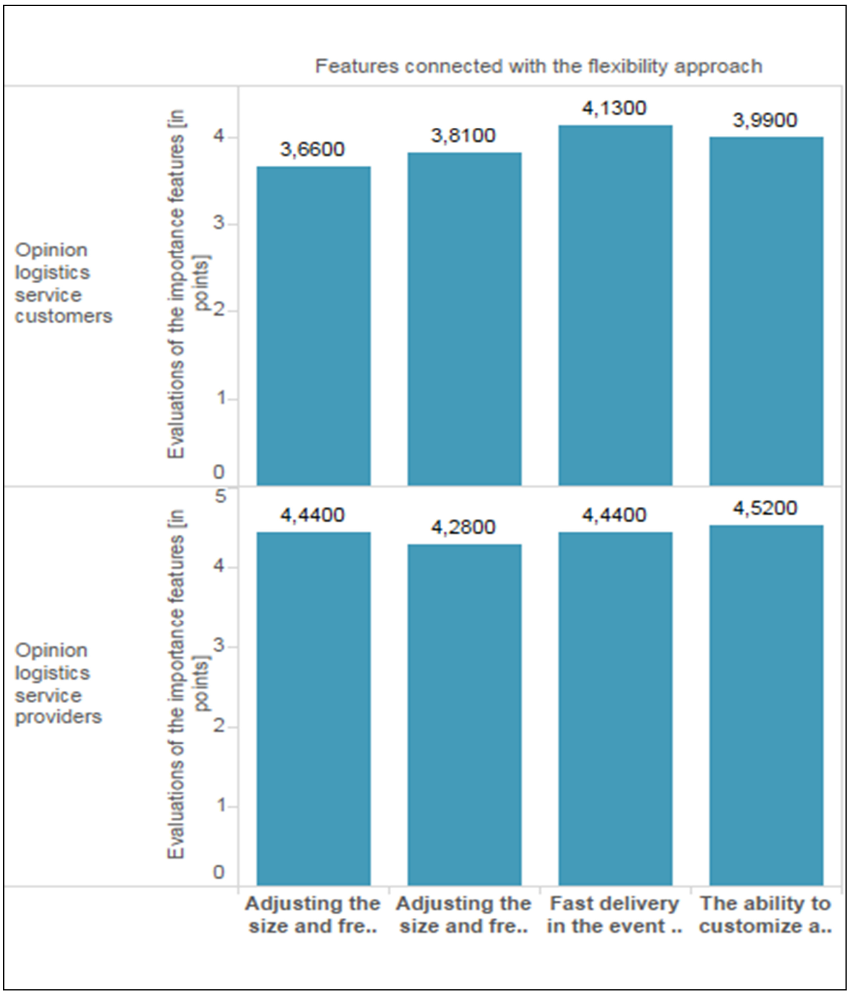


Figure 1 – A comparative analysis of the average ratings of the factors flexibility of supply

4. CONCLUSION

This paper investigates the problem connected with gain competitive advantage of companies. Flexibility of deliveries is one of the most important criteria for logistics providers as well as their customers. Taking into account the different levels of importance features, including the criteria affecting the quality of services, the authors proposed flexibility of deliveries models for the needs of service providers and purchasers using logistics services.

Comparative analysis of average grades importance of selected factors showed that the level of awareness of the considered medium flexible deliveries representatives of companies providing logistics services is slightly higher than the level of awareness of the companies purchasing logistics services. They testify assigned by representativeness of logistics services providers higher evaluations over than 4.28 pt., where 4 means high the importance features of flexibility of deliveries.

Typed factors were associated with the flexibility of deliveries in the enterprise and their participation in the above proposed assessment models.

The studies confirm the high importance of flexibility deliveries as a criterion in the assessment of logistics services.

On the basis of the analysis can be concluded, that flexibility of deliveries may be an important factor for logistics companies to gain a competitive advantage. In turn proposed flexibility deliveries model can be the basis in transport companies in order to global evaluation of flexibility of deliveries determine.

5. REFERENCES

[1] Womack, J.P., Jones D.T., Roos D.: *The Machine That Changed the World: The Story of Lean Production– Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry* (Reprint ed.). New York: Free Press 2007.

[2] Pan, Z., Tang, J., Fung R.: *Synchronization of inventory and transportation under flexible vehicle constraint: A heuristics approach using sliding windows and hierarchical tree structure*, European Journal of Operational Research 192/3 (2009), 824–836.

[3] Krämer, A., et al*., Cost effects of delivery frequency from logistics service providers perspective*, European Transport Conference, 2010.

[4] Krämer A., Krämer J.: *Flexibility of delivery frequency in logistics competition*. Working Paper, Karlsruhe Institute of Technology 2010.

[5] Gajewska, T., Filina-Dawidowicz L.: *Modelling dimensions of quality assessment of logistics services in road refrigerated transport*, 5th IEEE International Conference on Advanced Logistics and Transport (ICALT), Kraków, Poland 2016 (in press).

[6] Gajewska, T.: *Poziom konkurencyjności przedsiębiorstw świadczących usługi logistyczne w zakresie transportu chłodniczego*, Logistyka 3 (2015), 1336–1344.

[7] Goffin, K., Szwejewski M., New C.: *Managing suppliers: when fewer can mean more*, International Journal of Physical Distribution and Logistics Management, 27/7 (1997), 422–436.

[8] Lorenc, A., Szkoda M.: *Customer logistic service in the automotive industry with the use of the SAP ERP system*, 4th IEEE International Conference on Advanced Logistics and Transport (ICALT). Valenciennes, France 2015, 18–23.

[9] Ha, A.Y., Li L., Ng S.-M.: *Price and delivery logistics competition in a supply chain*, Management Science 49/9 (2003), 1139–1153.

[10] Yang, C.C., Marlow P.B., Lu C.S. *Assessing resources, logistics service capabilities, innovation capabilities and the performance of container shipping services in Taiwan*, International Journal of Production Economics 122/1 (2009), 4–20.

[11] Brdulak, H.: *Satysfakcja klientów w branży TSL*, Rzeczpospolita 72 (2009).

[12] Jezierski, A.: *Multiperspektywistyczne definiowanie jakości procesów logistycznych w dobie konsumenckiej*, LogForum 1/2 (2005), 1–7.

[13] *Special Report. Operator Logistyczny Roku 2014*, Data Group Consulting 2014.

[14] Kisperska-Moroń, D. (red.) Krzyżaniak S.: *Logistyka*, ILiM. Poznań 2009.

USING SIMULATION TO ENHANCE PROCUREMENT SOURCING DECISIONS

Allen GREENWOOD[1], Travis HILL[2], Chase SAUNDERS[2], Robbie HOLT[2]

[1]Poznan University of Technology, Faculty of Engineering Management
Strzelecka 11, Poznan,
Poland
[2]Mississippi State University, Center for Advanced Vehicular Systems Extension
153 Mississippi Parkway, Canton, MS,
USA

Abstract:

The material procurement sourcing decision is complex, includes considerable variability and uncertainty, especially for international options, and significantly impacts enterprise performance. Acquiring the material usually requires multiple transportation modes and large distances. This paper describes a simulation-based system to support sourcing decisions by enabling the rapid development of simulation models of both domestic and international supply paths. Simulation models are used to assess the impact of selecting alternative suppliers in an uncertain environment. The decision-support system is demonstrated via a case study where a US-based automotive assembly plant assesses the impact of obtaining transmissions from domestic and international supplier.

Keywords:

simulation, intermodal transportation, materials procurement, sourcing decsion

1. INTRODUCTION

Manufacturing organizations select material suppliers from many possible sources, both domestic and international, and use multiple modes of transportation, e.g. rail, truck, and ocean carrier, to obtain the material. In order to obtain and maintain competitive advantage, organizations receive raw materials and components from all over the world. For example, products may be developed in Europe and the U.S., manufactured in Asia and Latin America, and sold worldwide [1]. In order to move materials or products through a global supply chain, e.g. from the Far East to North America or Europe, multiple handoffs are required [2]. Among these handoffs are varying modes of transportation, such as truck, railroad or ocean carrier. The transfer across multiple modes is referred to as intermodal. For example, items shipped in containers by ocean carrier usually must be transferred to rail or truck several times.

Sourcing decisions are a critical part of the acquisition process and in most industries they drive manufacturing and product performance; as noted in [3], "(p)roduct outsourcing is recognized as a way to gain the flexibility necessary for competitive advantage." Critical elements of sourcing decisions include specifying from where to acquire the needed material, in what quantity, and deciding the modes to use to get the material from a supplier to the manufacturer. As such, the decisions are complex, involve considerable variability and uncertainty, and significantly affect organizational performance in terms of cost, timeliness of production, quality, batch size, inventory, etc.

Simulation is a common means to study complex systems and evaluate the consequences of alternative actions before making decisions and committing resources. As described in [4], simulation is a process for considering key aspects of a real system as simplified, yet representative, models and experimenting with the models to gain insight and support the decision-making process. In this paper, simulation is applied to the sourcing decision and selecting among alternative suppliers.

The use of simulation in supply chain design and management can occur at various levels. Good overviews of transportation logistics and global supply chain design are described in [5,6], respectively. Detailed discrete-event simulation models have been developed to represent the operations of key elements in the supply chain. For example, in [7] the activities in a Japanese container terminal are modeled in order to analyze bottlenecks and improve performance within the terminal. The approach described in this paper represents such elements at a much higher level and their interaction with other high-level elements. Of course, detailed models provide a good means for abstracting to a higher level and identifying key performance drivers. These detailed models are complementary, not contradictory, to the approach described in this paper. In [3], simulation is used to assess supply chain performance in the furniture industry. They provide a good overview of the issues and clearly demonstrate the importance of applying simulation to analyzing the impact of outsourcing on supply chain performance. This paper builds upon their work and extends the capabilities of their models in several important ways.

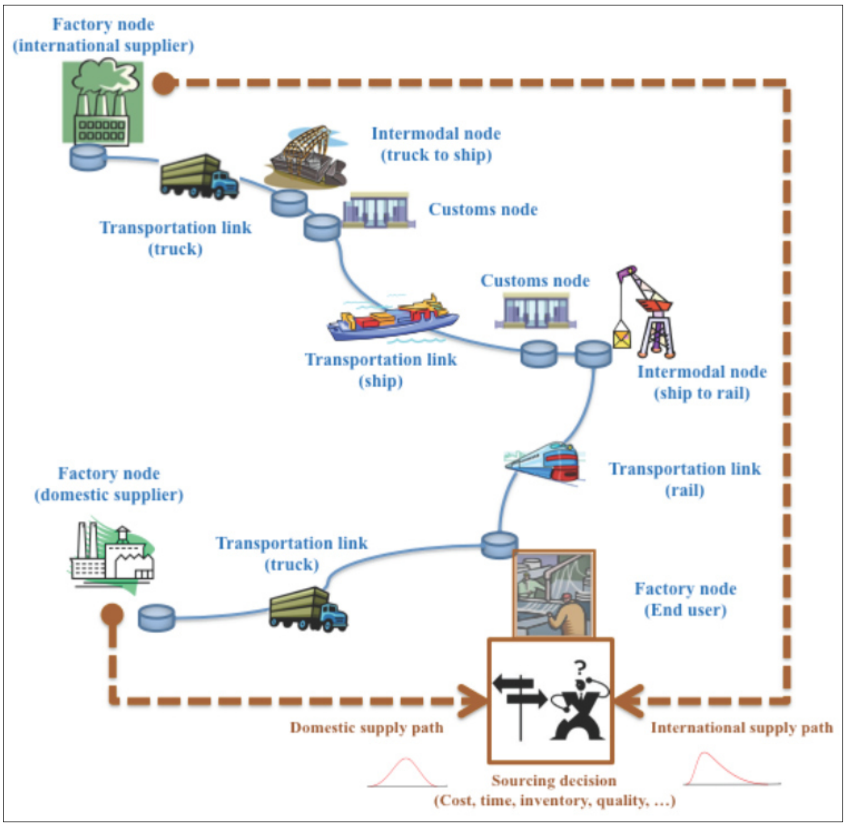


Figure 1 – Examples of high-level domestic and international intermodal paths formed by assembling node and link objects

To make simulation more readily available to decision makers, this research develops a library of general simulation objects. These objects represent key intermodal supply chain elements that can be combined very rapidly to develop simulation models for assessing the performance (e.g. lead time, variation in lead time) of alternative domestic and international intermodal supply paths in any industry. As illustrated in Figure 1, intermodal transportation *paths* between supplier and end-user are composed of a series of intermodal *nodes* (e.g. container port, rail yard) and *links* (e.g., roadways, rail lines, shipping lanes). The nodes and links are simulation modeling objects that contain basic operational logic and data values for properties that represent its operation and performance. Once the objects are assembled into paths, they can be simulated and used to assess lead times, lead time distributions, costs, risks, etc.

Since most intermodal global supply chains use containers for transport, the basic unit of transport in the system is the container. Ships, trucks, and trains/rail all convey containers that are transferred from one mode of transportation to another at ports and terminals.

This paper is organized as follows. Section 2 describes the simulation-based decision-support system. Section 3 demonstrates the use of the system via an illustrative example from the U.S. automotive industry. Section 4 provides conclusions and areas for future research.

2. SIMULATION-BASED DECISION-SUPPORT SYSTEM

The simulation-based decision-support system for analyzing supply paths uses an object-oriented architecture and employs data and user interfaces to facilitate its use by those with little non-simulation experience. The system is primarily developed using *FlexSim* simulation software and is composed of two broad classes of modeling objects, nodes (factories and transportation hubs) and links. There are two types of factories – end-user, the focus of the analysis, and suppliers. A single common object could represent all factories, but for ease of use, they are represented as two types of objects. A single object, the transportation hub, can represent all intermodal objects, such as ports, rail yards, and truck terminals. Similarly, a single object, the transportation link, can represent all means of transportation, trucks on roadways, trains on railways, and ships on sea-lanes.

The left-hand side of Figure 2 illustrates how a real system, a container port in this case, can be abstracted so that its operation is approximated by the intermodal transportation hub object in a simulation model. By specifying object properties the general transportation hub object is customized to represent a specific port. Some of the properties that define its capability and operation are supplied to the object via graphical user interfaces; an example is shown in the right-hand portion of Figure 2.

The internal logic of a transportation hub object is shown in Figure 3. Basically, containers are separated from their means of transport as they enter the hub, are placed in a central container queue, and then are loaded onto their outgoing means of transport. Delays represent loading and unloading times and other relevant activities in the hub. Storage areas represent temporary delays encountered while waiting for the required resources.

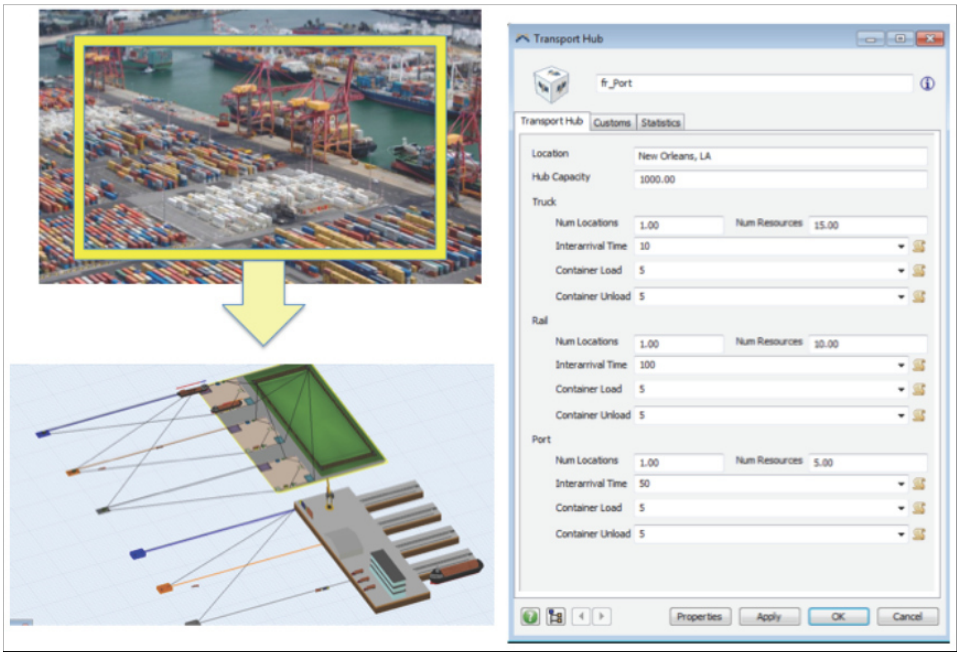


Figure 2 – Representation of port operations via the decision-support system's transportation hub object

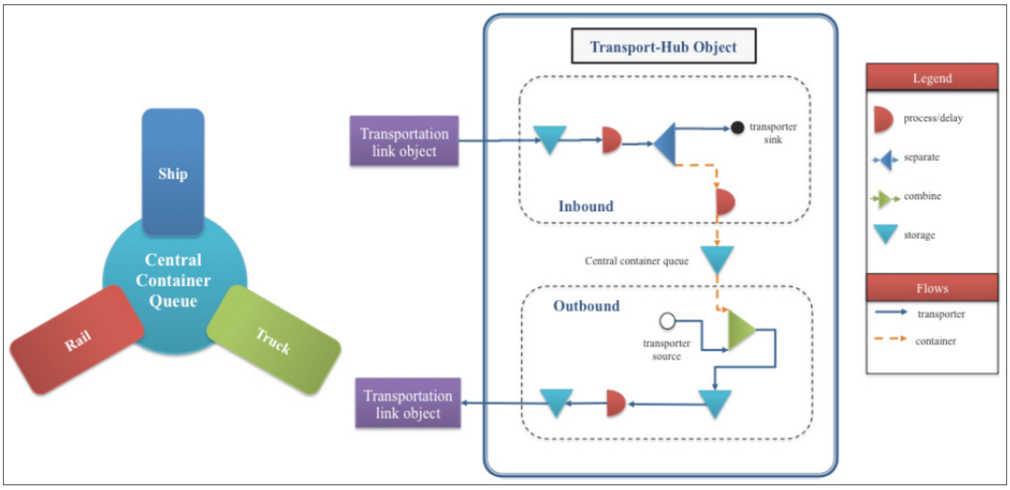


Figure 3 – Underlying logic of the transportation hub object

Figure 4 shows the internal logic of a general factory object. This object is actually implemented in the decision-support system as two objects – end-user factory and supplier factory. The end-user object is the most complex and incorporates most of the logic shown in Figure 4. It only lacks the link between the postorder delay and finished good storage and the customer, since it serves the market. The internal operations of the supplier factory are not modeled since such detail is likely unknown. Therefore, the activities in the lefthand portion of the logic diagram in Figure 4 are not included in the supplier object. The supplier object also does not include the supplier and market symbols – the suppliers of the supplier are not considered and it serves a specific customer (the end-user factory) and not a market.

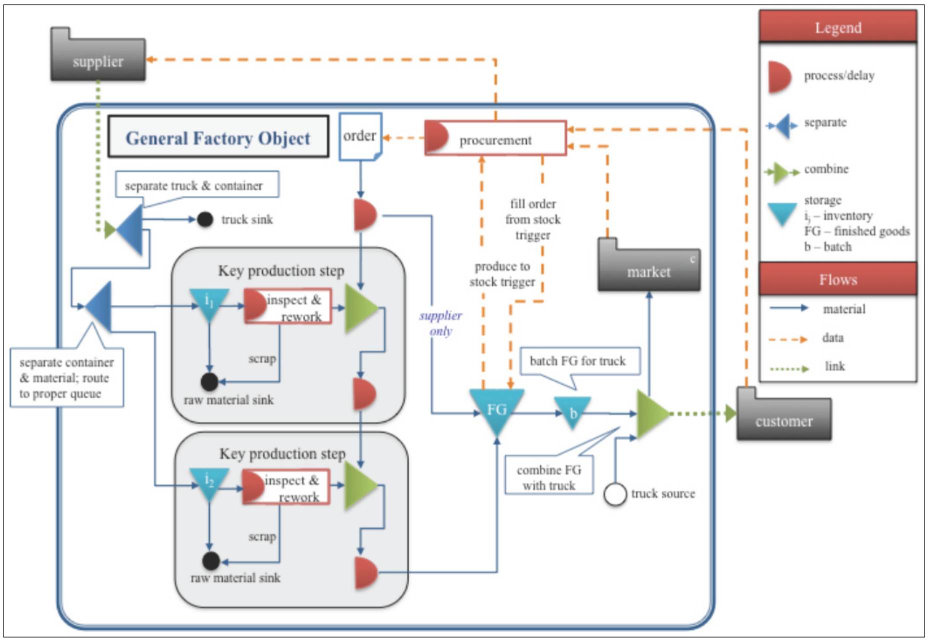


Figure 4 – Underlying logic of a factory object

As shown in Figure 5, link objects represent the movement of containers via a means of transport (truck, train, ship) between nodes, i.e., factories and transportation hubs. In the example in Figure 5, a rail link is defined to move containers between NYC and SAN by train and a road link is defined to move containers between NYC and DFW by truck.

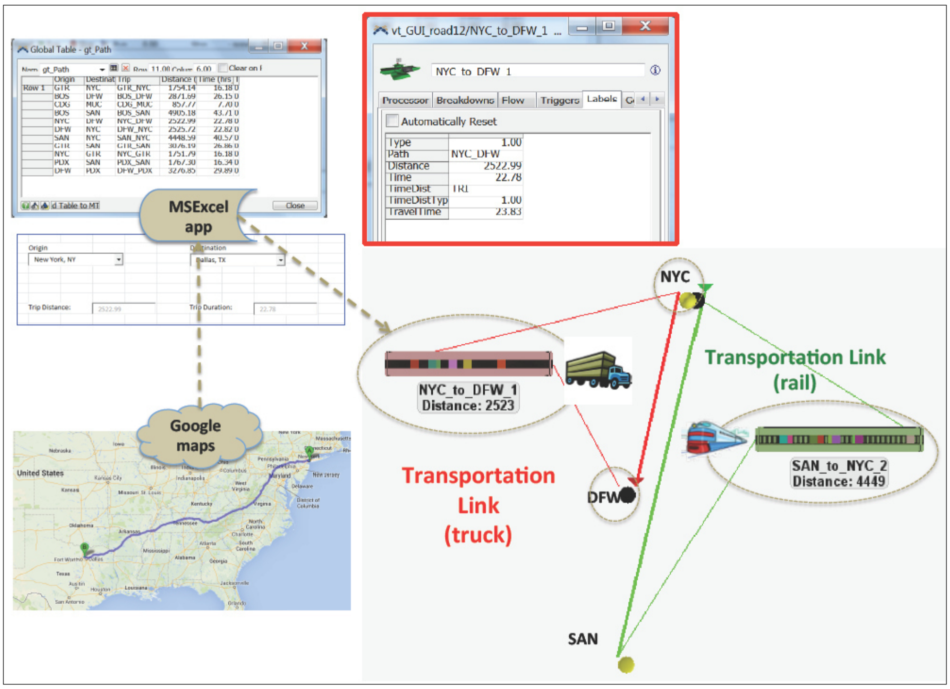


Figure 5 – An example transportation-link object and the population of its properties

The link object automatically obtains attribute values, e.g., distance and travel time, when a connection is made between the source and destination objects/locations. An example of the data stored on the link object is shown in Figure 5. The distances and times are stored within the simulation model as a global table by mode of transportation. The values can be obtained from various sources, e.g. *Google Maps*, and can be populated manually or from an external source, such as a simple *MS Excel* file or an online provider (e.g. *Google Maps*). In this system, time and distance information are obtained from *Google Maps* via a *Visual Basic Application* (*VBA*) program and stored in a *MS Excel* spreadsheet that is read by the simulation model. The *VBA* interface and an example spreadsheet table are shown in Figure 5. It is possible to access *Google Maps* directly from within the simulation software (through application commands in *FlexSim*), but may negatively impact the runtime performance of the simulation model.

A key concern in assessing the performance of alternative supply paths is the risk of not receiving goods when expected. Oftentimes the issue is the risk of lateness, but receiving goods too early can also be a concern since there may not be sufficient storage space at the receiving location. There is also an increased risk of damage when goods arrive earlier than needed. In order to assess risk, variability is introduced into

the simulation model via user-specified probability distributions in the applicable object. Travel time data values are assumed to be means or averages. The mean times are transformed to triangularly distributed random variables in the simulation models using the triangular-distribution parameterization method developed in [8]. Of course, any probability distribution can be used in the simulation models; the triangular is used because it is intuitive and simple, but representative.

Airport codes are used to represent locations. While a variety of different location codes and formats were considered, including using a full address, the standard 3-letter airport code was chosen for this implementation.

3. INDUSTRY CASE STUDY USING THE DECISION-SUPPORT SYSTEM

A case-study example is used to illustrate the application of the simulation-based decision-support system for evaluating sourcing alternatives. Data used in the simulation models are obtained from an automotive assembly plant, ports, and the internet (distance information for roadways from *Google Maps*). Since the study is based on a real situation, the data values are representative, but have been modified so as to not violate non-disclosure agreements and reveal proprietary information.

The example involves deciding between two potential suppliers that would provide transmissions to an automotive assembly plant located in Mississippi. One supplier is located in Japan, the other in Tennessee. For both locations, the number of transmissions per container and the supplier lead times are the same. The period of performance for the analysis is two years.

The international supply chain, from Japan to Mississippi, includes the supplier, an intermodal transportation network and the automotive assembly plant (end user). The transportation network is comprised of various transportation links (i.e., roadways, railways, and seaways) and transportation hubs (e.g. ports and rail yards). As shown in a snapshot of the simulation model in left-hand portion of Figure 6, the process begins with an order being generated by the end user for the supplier in Japan. The minimum order quantity is four containers. Each order is processed through the supplier and each container load of transmissions is placed on a truck where it is transported to a port in Japan via a road-link object. At the port, the container is processed and loaded onto a ship where it travels to the port in Los Angeles via a sea-link object. It is unloaded, processed, and loaded onto a train with other containers. The train delivers the containers to the transportation hub in Tennessee where they are offloaded and individually leave the transportation hub via truck to the end user's factory. Once at the factory, each container is unloaded, transmissions are removed from the containers, and make their way through the production process.

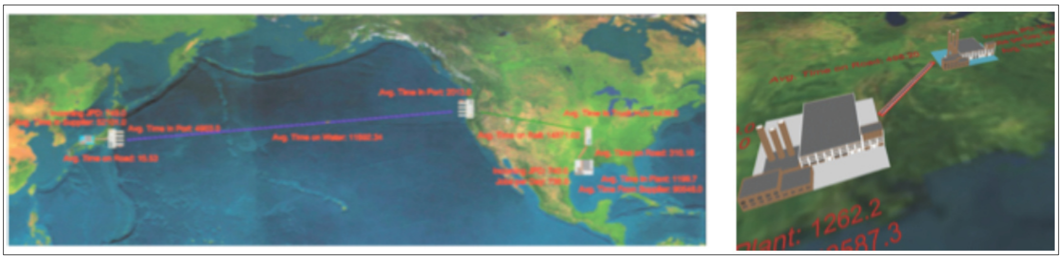


Figure 6 – Simulation models built from the decision-support system's objects to assess expected performance of an international supplier and a domestic supplier

The domestic supply chain, from Tennessee to Mississippi, is much simpler and only includes the supplier, a roadway and the automotive assembly plant. As shown in a snapshot of the simulation model in right-hand portion of Figure 6, the process begins with an order being generated by the end user for the supplier in Tennessee. The minimum order quantity is one container. Each order is processed through the supplier and each container load of transmissions is placed on a truck where it is transported directly to the end-user factory in Mississippi. Once at the factory, each container is unloaded, transmissions are removed from the containers, and transmissions make their way through the production process.

The simulation analysis considers three levels of risk – low, medium and high – to assess the impact of uncertainty on the automotive assembly plant's operational performance. Risk represents variation in various aspects of the supply chain such as travel times and supplier lead times. Low risk is defined as ±5% of the mean, medium risk between -5% and +15%, and high risk between -5% and +30%.

Three primary performance measures are considered. The first is the average time in the system, which measures the time from when an order is placed until the corresponding finished goods are completed. The second is average jobs per day, which is a measure of throughput and is used to ensure the supply chain is meeting the automotive assembly plant's desired rate. The third measure is end-user incoming buffer capacity. It is a measure of the storage space in the end-user factory needed to absorb the fluctuations caused by ordering constraints and intermodal delays.

Table 1 summarizes the comparison between the two suppliers (international and domestic) in terms of the three primary performance measures defined above and the three levels of risk. All values in the table are mean values. The upper and lower confidence interval limits for the first two measures (time in system and jobs per day) are within 0.2% of their mean, based on ten replications. Similarly, the limits for end-user factory's buffer capacity are within 8% of their mean, again based on ten replications. There is no significant statistical difference in throughput (jobs per day) between the two suppliers or among the risk levels, implying both supply paths are capable of meeting market demand.

Table 1 – Performance measures by level of risk for each alternative supplier

	Average Time in System (hours)	Jobs per day	End User Factory Incoming Buffer Capacity (units)
International (Japan)			
Low	1458.8	744.9	649.3
Medium	1503.2	743.6	541.4
High	1571.2	744.4	470.1
Domestic (Tennessee)			
Low	850.1	743.1	21.9
Medium	878.4	742.4	31.6
High	920.9	740.2	41.0

In terms of average time in the system, as expected, the international supplier takes considerably longer. Similarly, as expected, time in system increases for both suppliers as variability increases.

A plot of the simulation results (ten replications for each risk level and each supplier) is provided in Figure 7 for the end-user factory's incoming buffer capacity. As expected, the required buffer capacity is much larger for the international supplier. However, the risk comparisons are interesting. The domestic supplier's effect on buffer capacity is what might be expected – it increases as variability in the system increases. In fact, the capacity at the high-risk level needs to be nearly twice the low-risk level. However, for the international supplier the needed storage capacity decreases with increasing risk levels. This is due to the very long time in system – the longer it takes for containers to reach the factory, the more production consumes, and thus there is less inventory.

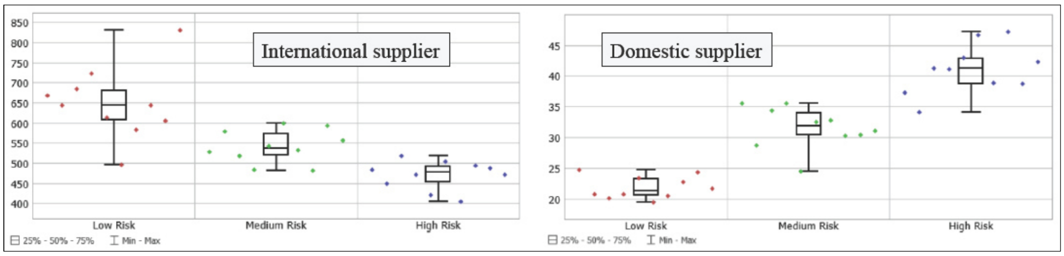


Figure 7 – End-user factory's incoming buffer capacity for international and domestic suppliers

4. CONCLUSIONS

This paper demonstrates the feasibility of developing and using a high-level simulation-based decisionsupport system for selecting alternative suppliers based on characteristics of their supply paths. Alternative supply paths are quickly created using nodes, that represent factories and transportation hubs, and paths that connect the nodes and represent modes of transportation, such as truck, train, and ship. The supply paths are models that can then be simulated and analyzed in order to assess and compare supplier performance in an uncertain environment. The system is general enough to accommodate a range of options at various levels of complexity. Data entries, that enable the nodes and paths to represent specific elements in the system, are made though easy-to-use interfaces. The system is developed using the state-of-the-art simulation software *FlexSim.* The system's capability to rapidly model and analyze competing supply chains is demonstrated through an industrial case study. It is used to assess alternative supplier impacts on the performance of an end-user factory. While cost attributes are incorporated into the decision-support system, a cost analysis was not performed due to the limitations of available data, In addition, rework/scrap data was not available for the end-user factory, which limited the assessment of impacts on its performance.

Future work would make the decision-support system more flexible and additional case studies should be considered and evaluated to ensure the system can handle a wide range of supply-chain requirements. Although size of the order quantity, demand, and period of performance were considered, additional analysis of the effect of these factors would enhance sourcing decisions. The simulation-based system described in this paper provides a foundation for comparing the costs of the alternative supply chains. However, it needs to incorporate a more holistic cost framework, such as described in [9].

5. ACKNOWLEDEMENTS

The authors thank the U.S. Department of Transportation and the National Center for Intermodal Transportation for Economic Competitiveness (NCITEC Project No. USDOTDTRT12-G-UTC14); Mississippi State University's Center for Advanced Vehicular Systems Extension, Department of Industrial and Systems Engineering, and the Franklin Furniture Institute; Faculty of Engineering Management at Poznan University of Technology; and, industrial partners: Alabama State Port Authority, FlexSim Software Products, FlexSteel Industries Inc., Miller Transport, Moffatt and Nichol, Nissan North America Inc., and the Port of New Orleans for their support for this project.

6. REFERENCES

[1] Burnson, P.: *Going Global Offers Both Pitfalls and Rewards*, Logistics Management and Distribution Report, 38(1992), 92.

[2] Russell, D., Saldanha, J.: *Five Tenets of Security Aware Logistics and Supply Chain Operations*, Transportation Journal. 42(2003), 44–54.

[3] Eksioglu, B., Eksioglu S., Zhang J., Jin M.: *A Simulation Model to Analyze the Impact of Outsourcing on Furniture Supply Chain Performance*, Forest Products Journal, 60 (2010), 258–265.

[4] Beaverstock, M., Greenwood A., Nordren W.: *Simulation Modeling and Analysis Using FlexSim*, FlexSim Simulation Products, Orem, UT, 2014.

[5] Goldsman, D., Truong S., Azadivar T.: *Simulation Of Transportation Logistics*, Proceedings of the 2003 Winter Simulation Conference, New Orleans, December 2003, 1268–1275.

[6] Meixell, M., Gareya V.: *Global Supply Chain Design: A Literature Review and Critique*, Transportation Research Part E, 41(2005), 531–550.

[7] Liu, Y., Takakuma S.:. *Modeling the Materials Handling in A Container Terminal Using Electronic Real-Time Tracking Data*, Proceedings of the 2011 Winter Simulation Conference, Phoenix, December 2011, 1596–1604.

[8] Jannat, S., Greenwood A.: *Estimating Parameters of the Triangular Distribution Using Non-Standard Information*, Proceedings of the 2012 Winter Simulation Conference, Berlin, December 2012.

[9] Zeng, A., Rossetti C.: *Developing a Framework for Evaluating the Logistics Costs in Global Sourcing Processes: An Implementation and Insights*, International Journal of Physical Distribution and Logistics Management, 33(2003), 785–203.

SCHEDULING OPERATION OF WIND POWERED PUMPED-STORAGE HYDROELECTRICITY

Jakub JURASZ[1], Jerzy MIKULIK[1]

[1]AGH University, Faculty of Management
al. Mickiewicza 30, Krakow,
Poland

Abstract:

This study investigates the benefits of using pumped-storage hydroelectricity (PSH) as an intermediary between wind turbines and power grid. The potential benefits are understood as a reduction in energy output variability scale and increase in dispatchability. The approach includes development of a simulation model, and energy generation scheduling method. Simulation was conducted for wind speed data covering period from 2013 to 2015. From the calculations we find that proposed power unit is capable of ensuring reliable and dispatchable energy generation for next 25 to 48 hours.

Keywords:

energy storage, hybrid power source, variable renewable energy

1. INTRODUCTION

Increasing role of renewable energy sources (RES) is generally perceived as a positive phenomenon. However they not only usually come with greater investment costs but also create new challenges for the power grid operators. This is especially visible in case of the so called variable renewable energy (VRE) sources to which one may account photovoltaics and wind turbines. Their energy generation is weather driven and can be forecasted to a limited although still expanding extent [1,2]. After years of research on individual RES, which focussed on their application, increasing performance more and more papers concentrates on the RES integration to the power systems. Delucchi and Jacobson [3] identified seven ways which should facilitate this process. One of them is the usage of energy storage devices in order to overcome the intermittent nature of some RES. This papers presents a quite novel concept of wind powered PSH (WT-PSH) along with an energy generation schedule for next 25 to 48 hours. The aim of this paper was not to focus on economic evaluation but rather to investigate the impact of various WT-PSH parameters on power output coefficient of variation and energy surpluses.

2. RELATED WORKS

The concept of the PSH powered by an intermittent renewable energy source is a result of an increasing role of non-dispatchable generation in many power systems. For example according to Fraunhofer Institut für Solare Energiesysteme (www.energy-charts.de) the installed capacity of photovoltaics and wind turbines constitutes to respectively 21.4% and 23.6% of total power installed in German power plants. Such a huge amount of VRE in power system makes it management and operation much more challenging than in a situation when only the supply side of energy market is varying.

Using PSH as an intermediary between intermittent wind generation and transmission network is a very promising way of facilitating increasing share of RES in power system. So far, due to the greater costs, the so called *green energy* had priority in access to the power grid. It is the conventional power plants which had to adjust their power output to the varying energy generation from VRE. The concept of wind powered pumped PSH has been investigated on many levels. Bueno and Carta [4] described this hybrid as a one of most promising ways of increasing RES penetration in case of Canary Islands. Introducing proposed approach would result in conventional fuels consumption reduction and decreasing CO_2 emissions. Dinglin et. al. [5] investigated rather small (8 MW in wind turbines) wind powered PSH from the perspective of its economics. Obtained results indicate that power output variability from wind generation due to the PSH intermediary has been significantly reduced, a dispatchable power can be offered to the system and financial benefits therefore can be gained. Aihara et. al. [6] presented a novel method for creating WT-PSH operation schedule which enables increase in reliability and economy. Authors concentrated on power systems with large penetration of photovoltaics, however their intermittent nature makes this problem similar to that tackled in this paper. Additionally they have expanded the scope of their research in [7] presenting an optimization algorithm for a WT-PSH which lead to a decrease of thermal power plants cost and reduced energy shortages. Naturally the concept of WT-PSH has been extended and Kumano and Yokoyama [8] and they considered PSH being powered from both, photovoltaics and wind turbines. They pointed to the fact that accurate forecast of VRE generation lead to a decrease in power shortage and surpluses probability.

3. METHODS AND DATA

This section is divided into four subsections. First presents the conceptual design of the WT-PSH. Second presents a method for power/energy output estimation for wind generation. Third introduces mathematical model of the WT-PSH operation. The last one shortly describes data sources and their processing.

3.1. WT-PSH hybrid

The whole concept is based on the assumption that PSH can simultaneously pump water into the upper reservoir and generate electricity by releasing it into the lower reservoir. Therefore, PSH must be equipped with a set of pumping, as well as generating, water turbines. An overview of energy flow for the proposed hybrid energy source is presented in Figure 1.

For the purpose of this study a theoretical PHS power plant characterized by following parameters was employed. Its storage capacity amount to 200, 400 or 600 MWh and it is equipped with two sets of water turbines. One is used to pump water to the upper reservoir and the second is used to generate electricity. Both were assumed to be able to generate 10 or 20 MWh of electric energy or pump a volume of water equal to 10 or 20 MWh of electric energy stored in upper reservoir in one hour. The efficiency of each set is equal to 90%. Which results in overall efficiency of 81%.

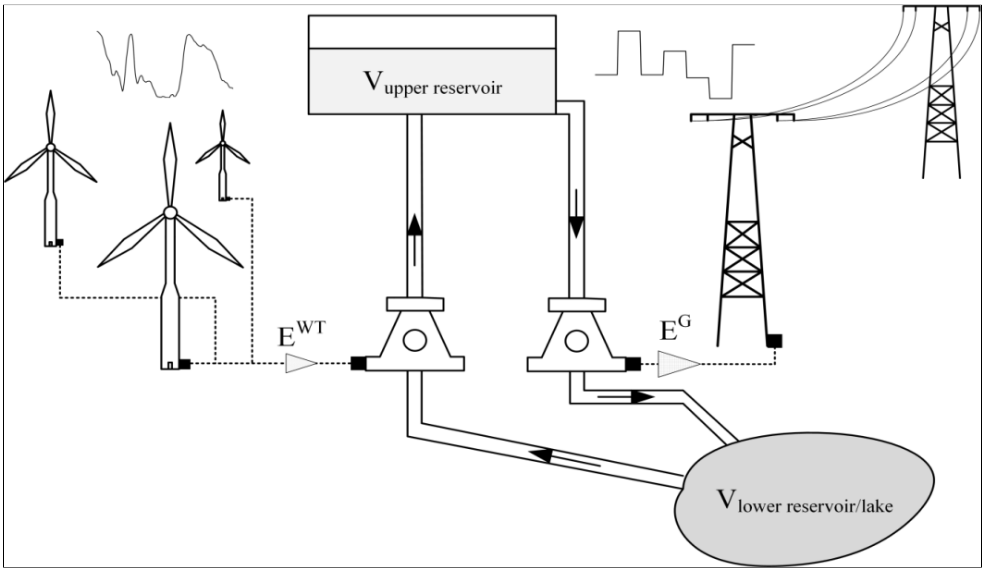


Figure 1 – Schematic energy flow of wind powered PHS

3.2. WT power output

Wind turbines vary in size, nominal power, cut-in and cut-off speed as well hub height. For the purpose of this study the Enercon E-82 E2 wind turbine with rated power of 2.05 MW has been selected. It is characterized by relatively low cut-in speed, as shown on Figure 2. The energy output for this wind turbine has been calculated based on formula (1). Indices in all formulas are: $i = 1, \ldots, m$ where m is equal to 1095 and $j = 1, \ldots, n$ where n is equal to 24 (i denote days and j – hours).

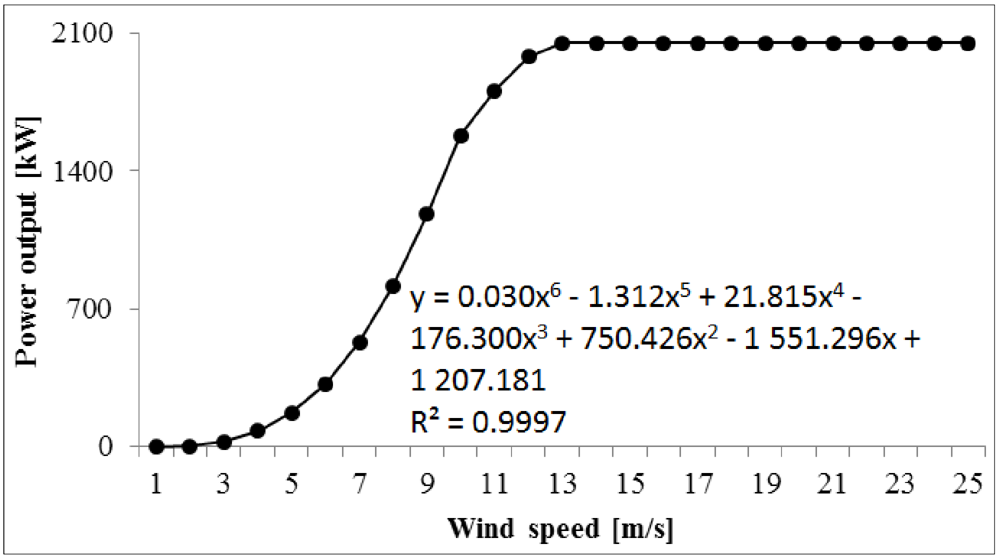


Figure 2 – Enercon E-82 E2 power curve along with a sixth degree polynomial approximating power output for wind speeds ranging from 2 to 12 m/s (data source: http://www.enercon.de/)

$$E_{i,j}^{TW} = \begin{cases} 0 if v_{i,j} < v_{cut-in} \\ N * P_{poly}^{TW} * t if v_{cut-in} \le v_{i,j} < v_{rated} \\ N * P_{rated}^{TW} * t if v_{rated} \le v_{i,j} < v_{cut-off} \\ 0 if v_{ij} \ge v_{cut-off} \end{cases} \quad (1)$$

for $i= 1...m; j = 1...n$, where $v_{i,j}$ – wind speed at hub height [m/s], v_{cut-in} – cut-in wind speed [m/s], $v_{cut-off}$ – cut-off wind speed [m/s], v_{rated} – wind speed at which wind turbine operates at its rated capacity [m/s], P_{rated}^{TW} – wind turbine rated capacity [MW], P_{poly}^{TW} – sixth degree polynomial approximation of wind turbine power output [MW], N – number of wind turbines, t – time [1 hour], $E_{i,j}^{TW}$ – wind generation energy output [MWh].

3.3. WT-HPS simulation, energy generation scheduling

Mathematical models are used to create a concise description of usually complicated systems by means of mathematical concepts and formulas. Very often in order to facilitate calculation process or even make it possible some simplifications and omission of factors with lesser impact may be necessary. In this study, an assumption has been made that influence of precipitation and evaporation on the volume of water (energy) stored in the upper reservoir will be neglected. Additionally it has be assumed that pumping and generating sets of turbines in PSH can process varying volume of energy without the change in efficiency. In order to simulate the behavior of WT-HPS a following mathematical model has been developed. The model starts by computing the value of ancillary variable $E_{i,j}^{B1}$ known further as an energy balance.

$$E_{i,j}^{B1} = V_{i,j-1}^{G} + \min(\eta_{PSH,P} E_{i,j}^{WT}; E_{\max}^{P}) - \frac{1}{\eta_{PSH,G}} E_{i,j}^{G} \quad (2)$$

for $i = 1, ..., m; j = 1, ..., n$ and $V_{1,0}^{G} = V^{GT}$, where $V_{i,j}^{G}$ – energy stored in the upper reservoir [MWh] and V^{GT} – is maximal energy storage capacity of upper reservoir [MWh], $\eta_{PSH,P}$ – PSH efficiency in pumping mode [%], $\eta_{PSH,G}$ – PSH efficiency in generating mode [%], $E_{\max}^{P}$ – maximal volume of pumped energy per unit of time [MWh], $E_{i,j}^{G}$ – scheduled energy generation [MWh] where for $i = 1, 2, ..., m$, $j = 1, ..., n$, $E_{i,j}^{G} = \frac{\eta_{PSH,P} * \eta_{PSH,G} * V_{i,j}^{G}}{2 * n}$ and $i = 3, ..., m$, $j = 1, ..., n$ is calculated based on formula (6), $E_{i,j}^{WT}$ – energy generated from wind turbines [MWh].

In order to determine the volume of energy stored in the upper reservoir two additional binary variables are introduced and their value is estimated based on formulas (3) and (4) respectively $b_{i,j}^{1}$ and $b_{i,j}^{2}$:

$$b_{i,j}^{1} = \begin{cases} 1, if E_{i,j}^{B1} > 0 \\ 0, otherwise \end{cases} \quad (3)$$

$$b_{i,j}^{2} = \begin{cases} 1, if E_{i,j}^{B1} > V^{GT} \\ 0, otherwise \end{cases} \quad (4)$$

for i = 1, ..., m; j = 1, ..., n,

Energy balance and binary variables are now used to determine the momentary volume of energy stored in the upper reservoir by means of following formula:

$$V_{i,j}^{G} = b_{i,j}^{1} b_{i,j}^{2} V^{GT} + b_{i,j}^{1}(1 - b_{i,j}^{2}) E_{i,j}^{B1} \tag{5}$$

for i = 1, …, m; j = 1, …, n.

After two day long (estimated arbitrary) model booting (i = 1, 2) a generation schedule for next 25 to 48 hours can be made based on the following formula:

$$E_{i,j}^{G} = \min\left[\max\left[\frac{V_{i,j=24}^{G} - 24E_{i-1,jj}^{G}\dfrac{1}{\eta_{PSH,G}}}{24\dfrac{1}{\eta_{PSH,G}}};0\right];E_{\max}^{G}\right] \tag{6}$$

for i = 3, …, m; $j = j$, ..., n, $E_{\max}^{G}$ – maximal volume of energy generated per unit of time [MWh].

Because proposed WT-PHS hybrid will be operating as a part of bigger energy system it is important to calculate the volume of the energy ($E_{i,j}^{S}$) that cannot be stored in the upper reservoir due to it limited capacity. From the perspective of the energy market balance this occurring surplus may be perceived as an unscheduled and unwanted generation. The form of energy generation scheduling formula (6) ensures situation when no energy deficit will occur – energy deficit is a situation when less energy will be generated than scheduled.

$$E_{i,j}^{S} = b_{i,j}^{1} b_{i,j}^{2} \mid E_{i,j}^{B1} - V^{GT} \mid \frac{1}{\eta_{PSH,G}} \tag{7}$$

for i = 1, ..., m; j = 1, ..., n.

3.4. Data acquisition and processing

Wind speed measurements taken by the Institute of Meteorology and Water Management – National Research Institute (IMGW PIN) are taken on a 10 meter high pole. Data which can be downloaded from Modern-Era Retrospective analysis for Research and Applications (MERRA) service (available at http://gmao.gsfc.nasa.gov/research/merra/) is also representative for this height. However wind speed data at this height is not adequate for a wind turbine which hub is sometimes as high as 100 meters above ground level. In case of considered in this study 2.05 MW ENERCON E-82 E2 wind turbine, the possible hub height in meters can be: 78; 84; 85; 98; 108; 138. For the purpose of this study it has been assumed that wind turbines hub will be 85 meters above ground level. The wind profile power law [9] has been applied to recalculate wind speed observed at 10 to that at 85 meters. In short, wind profile power law is a relationship between the wind speeds at one height and speeds at another. The formula presented bellow (8) has been applied for wind speed time series obtained from SoDa Solar Radiation Data (http://www.soda-pro.com/) for site described by following coordinates: 54.380133N, 16.689883E. This site is located in Sławieński District which by the end of the year 2015 had over 0.5 GWs installed in wind turbines (http://www.ure.gov.pl/) – what constitutes to almost 11% of installed capacity in Poland.

$$v = v_r \left(\frac{h}{h_r} \right)^{\alpha} \quad (8)$$

where: v – wind speed at height h, v_r – is the known wind speed at a reference height h_r, and the value of exponent α which is based on empirical studies and usually amounts to 0.143.

4. RESULTS AND DISCUSSION

Scheduling of WT powered PHS was conducted for three years long wind speed data time series consisting of 26280 recorded hourly values. The mean wind speed at a reference height of 10 meters for the mentioned in the previous section location was 5.57 m/s with a standard deviation (SD) equal to 2.52 m/s. Wind speed time series were then recalculated based on formula 8, and the mean wind speed increased to 7.56 m/s. The energy generation from a single wind turbine has been calculated based on formula 1 and the sixth degree polynomial presented in the Figure 1. Over those three years the mean annual energy generation per MW of installed capacity amounted to 3865 MWh. This gives a capacity factor equal to 42%. Table 1 summarizes basic statistical parameters of hourly energy generation within individual months. In general the energy generation in December is over 2.5 times greater than that in June. Additionally one can state that the greater the mean hourly energy generation the lesser is the value of the coefficient of variation (CV). After plotting mean energy generation and its corresponding CV values on a scatter plot the adjusted liner trend line had R^2 value equal to 0.967. The value of CV quite well characterizes the behaviour/variability of energy generation and therefore will be used in further comparisons between energy output from wind turbines and WT powered PHS.

Table 1 – Basic statistical parameters of hourly energy generation covering period 2013–2015

Month	Mean [MWh/MW]	Standard Deviation [MWh/MW]	Coefficient of Variation [%]
January	0.204	0.116	56.8
February	0.157	0.117	74.4
March	0.159	0.119	74.9
April	0.141	0.107	75.5
May	0.113	0.099	87.3
June	0.087	0.094	108.1
July	0.109	0.099	91.5
August	0.088	0.088	99.5
September	0.109	0.097	89.4
October	0.133	0.111	83.6
November	0.155	0.119	76.6
December	0.227	0.107	46.9

The operation of wind powered PHS has been simulated for three various storage capacities of PHS (200, 400 and 600 MWh) and two values of maximal energy pumping and generation potential of PHS (10MW and 20 MW). The combination of those parameters yields in six various configurations of PHSs. Figures 3 and 4 depict the scheduled values of energy generation in September 2015. In this simulation PHS was powered by a fleet of 20 wind turbines. In case of wind speeds exceeding 12 m/s their maximal energy output can be as high as 41 MWh per hour. Note how variable is this energy generation over 31 days in September (Figure 3). Within several hours it can reach its peak value and couple hours later not provide energy at all. Over this period energy yield from wind turbines often exceeded the scheduled energy generation and the storage capacity was not sufficient to accumulate this energy. The upper reservoir capable of storing as much as 200 MWh of energy was almost all the time full. Noticeable decreases in stored volume of energy can be observed in situation when wind generation is significantly dropping – however, never reaches zero. This implies that PHS will be generating electric energy all the time but the value of energy generation will vary from day to day. The changing energy generation from PHS is presented in Figure 4. Due to the constraints resulting from the structure of energy generation scheduling formula (formula 6) the maximal hourly energy output for each storage capacity is fixed and amounts to $V^{GT}/(24/\eta_{PSH,G})$.

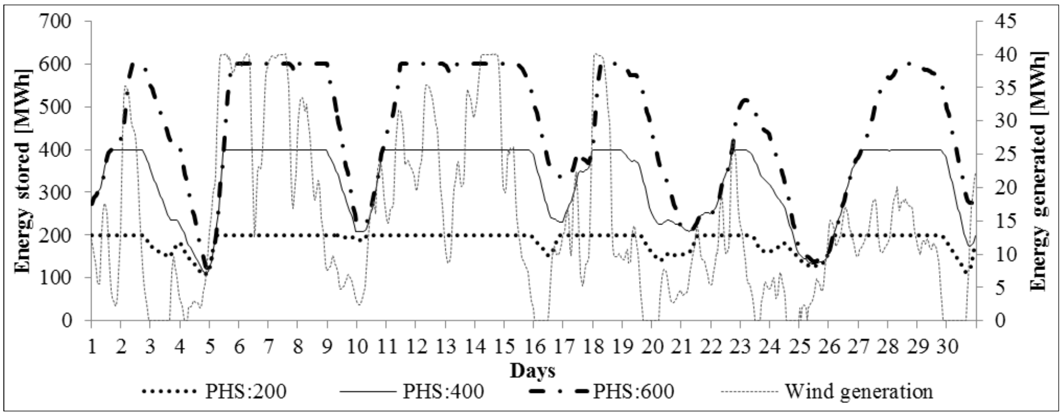


Figure 3 – Overview of energy stored in the upper reservoir and generated by wind turbines in September 2015. PHS pumping and generating capacity was 20 MW and PHS was supplied from 20 wind turbines, each 2.05 MW

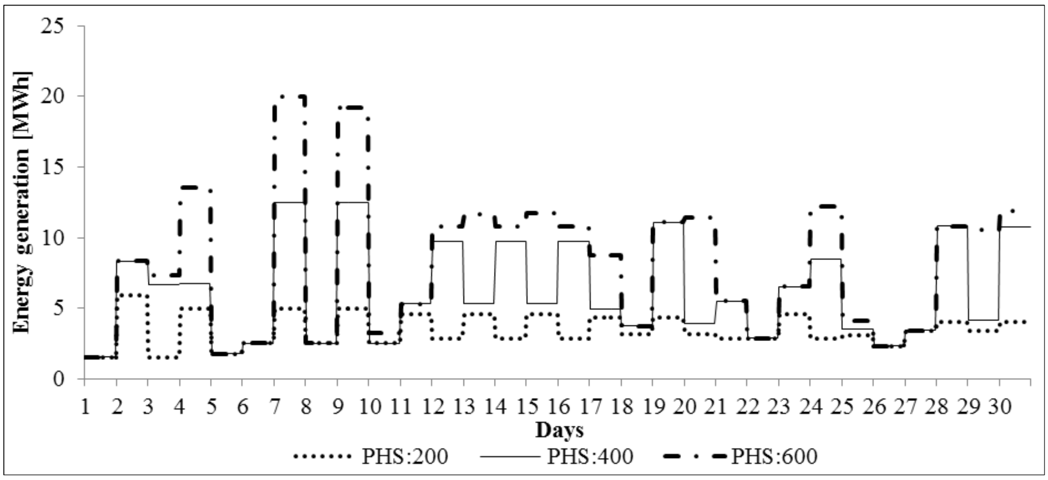


Figure 4 – PHS energy generation in September 2015 for various storage capacity scenarios (e.g. PHS:200 → storage capacity 200 MWh). Pumping and generating capacity as well as number of wind turbines is the same as in Figure 3

In case of scenarios presented in Figure 3 and 4 the mean hourly energy generation from PHS of storing capacity amounting to 200, 400 and 600 MWh was respectively 3.48, 6.15 and 8.21 MWh. Over this one month period wind turbine in each case generated 10.74 GWh of electric energy with mean hourly generation equal to 14.91 MWh. However due to the limited storing capacity and pumping/generating potential significant energy surpluses occurred. The WT powered PHS of storing capacity equal to 200 MWh had to reject slightly over 70% of energy generated from wind turbines. The PHS with twice the size of upper reservoir was capable of handling over 50% of energy generated, whereas the biggest one (600 MWh) was not able to process 31.5% of wind derived electric energy. The results presented above were obtained for arbitrarily determined number of wind turbines. Further analysis was conducted for changing number of wind turbines.

As can be seen on Figure 5, the increasing number of wind turbines leads to a situation when significant energy surpluses occur. PSH with a storage capacity of 200 MWh and 10 or 20 MW of power installed in water turbines is capable of accommodating energy from two wind turbines (4.1 MW). When the size of upper reservoir increases to 400 MWh this WT-PSH can handle energy from three wind turbines. In those both cases there are no visible differences whether 10 or 20 MW water turbines are considered. If greater upper reservoir is considered then the capacity of whole system to accommodate wind energy increases to almost 7 wind turbines (14.35 MW). PSH with 600 MWh storage capacities behave differently depending on the capacity of their pumps and turbines. The PSH with a greater (20MW installed in water turbines) capacity of pumping and generating electricity can absorb slightly more energy without rejecting it due to the limited storage potential. Greater pumping and generating capacity means in this case that energy can be retrieved from the upper reservoir much faster and in the same time more can be captured from wind turbines and pumped uphill.

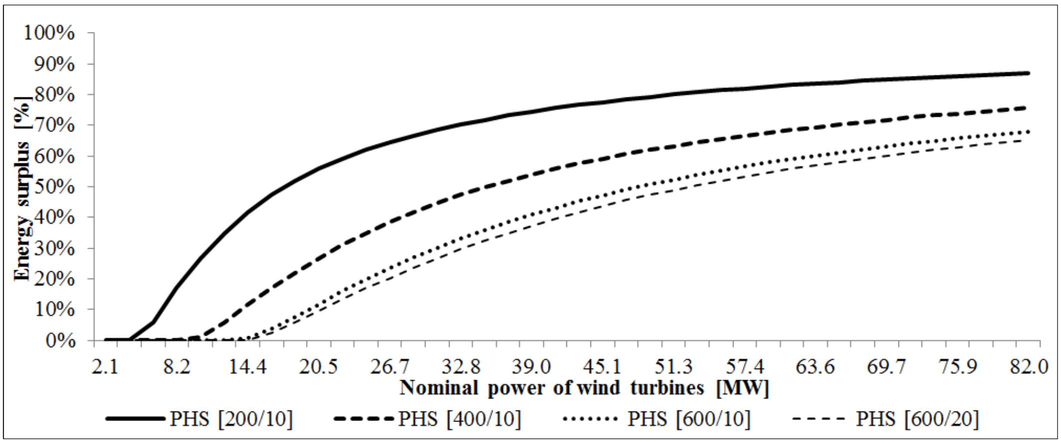


Figure 5 – Energy surplus share in total energy generated for various installed capacities in wind turbines for four different scenarios. Values obtained for scenarios PHS [200/20] and PHS [400/20] were identical with those for respectively PHS [200/10] and PHS [400/10] scenarios

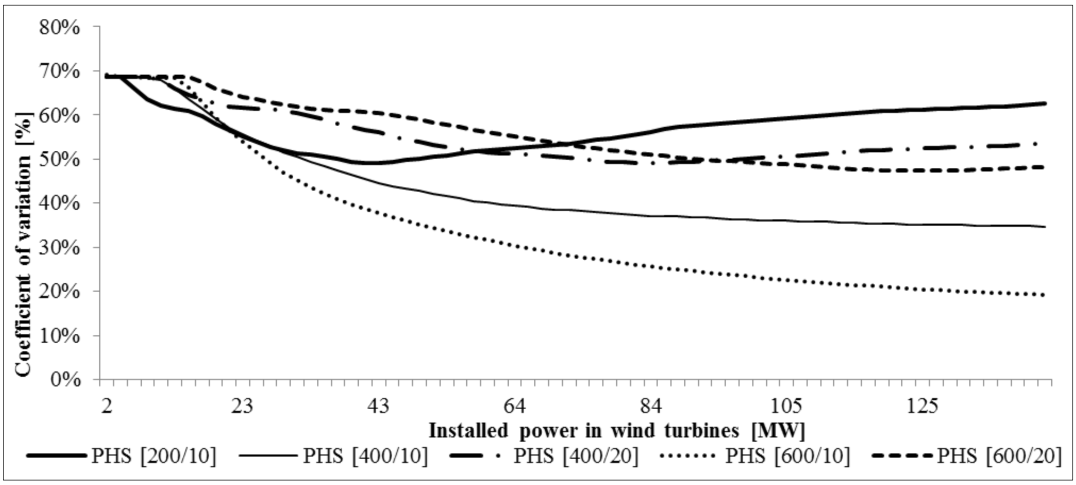


Figure 6 – Energy generation from PHS coefficient of variation for different installed capacities in wind turbines and five various scenarios. Results for PHS [200/10] and PHS [200/20] scenarios were the same

Interesting conclusions emerge when the value of CV is calculated for the hourly energy generation from PSH. In case of wind generation alone the CV value over those three years is equal to 122.6%. Applying PSH leads to a significant decrease in this measure, as it can be seen in Figure 6. However the patterns of changes in the CV values are not the same and vary for different WT-PSH characteristics. In case of PSHs with 600 MWh storage potential increasing number of the wind turbines which powers PSH pumps shows a constant decreasing trend. However the most significant reduction in CV is observed for power installed in WTs ranging from 10 to 30 MW. In remaining cases, the CV reaches in certain point its minimal value and then starts to increase again. This may be attributed to the fact that the potential of absorbing wind derived electric energy is limited to 10 or 20 MWh per hour. Due to the increased number of wind turbines the occurrence of periods with very low total sum of energy generated from WT dwindles. However there still remains periods with zero sum of energy from WT. In consequence the volume of energy stored in PSH drops and this leads to a change in scheduled values of energy generation. Presented results indicate, that from the perspective of CV values the storage capacity is much more important parameter than the power installed in water turbines. Greater storage capacity enables energy generation even in situation when the wind speed over several consecutive days makes it impossible to generate energy from wind turbines. In general applying PSH as an intermediary between wind park and power grid reduces the energy generation variability (CV) from over 120% to slightly less than 70%. Considering situation when energy surpluses should not exceed 1% of total sum of energy generated from WTs the suggested installed capacity in wind turbines would be: 6.15, 10.25 and 14.35 MW for PSH with storage capacity respectively equal to 200, 400 and 600 MWh. In case of PSH with 600 MWh storage capacity and 20 MW pumping/generating powers the installed power in WTs may be increased to 16.4 MW. For such parameters of WT-PSH the value of CV is reduced to on average 64%. One must bear in mind that this is the value calculated based on hourly values representing the whole three years period. Within a single day, WT-PSH energy generation does not exhibit any variability in comparison to wind generation itself.

5. CONCLUSSIONS

Coupling wind turbines with PSH creates a fully dispatchable power source. Proposed in this study scheduling formula reduces the overall energy generation coefficient of variation and what is very important eliminates the intra-day energy generation variability. The energy generation values are known from 25 to 48 hours prior to the hour when they will be generated. Obtained results point to the several interesting directions for future studies. A more meticulous analysis is needed in area of PSH storage capacity and water turbines/pumps power impact on energy generation variability and the occurrence of energy surpluses. An optimization model should be developed in order to optimize the parameters of WT-PSH what will lead to better exploitation of available wind energy. Additionally scheduling formula should be expanded in a way that will consider the changing value of the energy on the energy market. Future studies should also consider solar energy since its exhibits to some extent a positive correlation with daily power demand in Poland [10] and is complementary to wind and water energy [11].

6. REFERENCES

[1] Kleissl, J.: *Solar energy forecasting and resource assessment*, Academic Press 2013.

[2] Jung, J., Broadwater R.P.: *Current status and future advances for wind speed and power forecasting*, Renewable and Sustainable Energy Reviews, 31(2014), 762–777.

[3] Delucchi, M.A., Jacobson M.Z.: *Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies*, 2014 Energy Policy, 39(3)(2011), 1170–1190.

[4] Bueno, C., Carta J.A.: *Wind powered pumped hydro storage systems, a means of increasing the penetration of renewable energy in the Canary Islands*, Renewable and Sustainable Energy Reviews 10(4)(2006), 312–340.

[5] Dinglin, L., Yingjie C., Kun Z., Ming Z.: *Economic evaluation of wind-powered pumped storage system*, Systems Engineering Procedia, (4)2012, 107–115.

[6] Aihara, R., Yokoyama A., Nomiyama F., Kosugi N.: *Optimal operation scheduling of pumped storage hydro power plant in power system with a large penetration of photovoltaic generation using genetic algorithm* , In: PowerTech, 2011 IEEE Trondheim, 1–8.

[7] Aihara, R., Yokoyama A., Nomiyama F., Kihara H.: *Optimal operation scheduling of pumped storage hydro power plant using efficient optimization algorithm*, In Power System Technology (POWERCON), 2012 IEEE International Conference, 1–6.

[8] Kumano, J., Yokoyama A.: *Optimal weekly operation scheduling on pumped storage hydro power plant and storage battery considering reserve margin with a large penetration of renewable energy*, In Power System Technology (POWERCON), 2014 IEEE International Conference, 1120–1126.

[9] Peterson, E.W., Hennessey Jr. J.P.: *On the use of power laws for estimates of wind power potential*, J. Appl. Meteorology, 17(1978), 390–394.

[10] Jurasz, J., Mikulik J.: *Investigating Theoretical PV Energy Generation Patterns with Their Relation to the Power Load Curve in Poland*, International Journal of Photoenergy 2016.

[11] Jurasz, J., Piasecki A.: *Evaluation of the complementarity of wind energy resources, solar radiation and flowing water – a case study of Piła*, Acta Energetica (2016).

DEMAND FORECASTING WITH THE USAGE OF ARTIFICIAL NEURAL NETWORKS ON THE EXAMPLE OF A DISTRIBUTION ENTERPRISE

Krzysztof JURCZYK[1], Katarzyna GDOWSKA[2] Jerzy MIKULIK[3], Wojciech WOŹNIAK[4]

[1]AGH University of Science and Technology, Faculty of Management
Mickiewicza 30, 30-059 Krakow,
Poland

Abstract

In the paper the problem of demand forecasting with the usage of artificial neural networks (ANN) is presented. The literature review was prepared and analyzed. The related numerical example was prepared based on the data from an distribution enterprise. The results from using the proposed neural model were compared with the results of using exponential smoothing methods and seasonal indices forecasting methods. An impact of an established demand forecast on inventory level has been discussed.

Keywords:

artificial neural networks (ANN), customer service level, demand forecasting, inventory management, time series analysis

1. INTRODUCTION

Effective supply chain management is one of the most important decision problem in enterprises. Planning decisions related to this business operation area are mainly concerned with an efficient inventory management, i.e. the one that you can avoid unnecessary excessive warehouse stocks and same time provide the required service level.

Minimizing of inventory levels can reduce the stock carrying (holding) costs. On the other hand, higher stock levels guarantee a higher customer service level. These two statements allow to conclude that the selection of an appropriate inventory control strategy has its source in market demand for these inventories.

Correct demand pattern analysis and determination of reliable forecasts allow to reduce the stock carrying (holding) costs, especially capital costs (or financing charges) and storage space costs. As a result, reliable demand forecasts allow to dynamic adjustment of inventory levels to market requirements and to increase inventory turnover ratio. Going further, high inventory turnover ratio value allow to increase the enterprise financial liquidity.

In the paper, the analysis of the possibility of using artificial neural networks to forecast demand level at some distribution enterprise was introduced. Before the achieved results will have been presented, a related literature review is necessary to introduce.

2. RELATED LITERATURE

Nowadays, there has been a growing interest in non-conventional demand forecasting methods, which in better way allow for the inclusion of uncertainties and imperfect information [1–8]. Among such techniques, artificial neural networks (ANN), which has been discussed widely in the recent literature, can be mentioned.

The concept of artificial (formal) neuron was first introduced in 1943 by W. S. McCulloch and W. Pitts [9]. The authors proposed a formal calculus system for different kinds of neurons' nets based on threshold logic. The first application of ANNs approach for forecasting was introduced by M. J. C. Hu in 1964 [10]. The author used Widrow's adaptive linear network to weather forecasting. Unfortunately, there has not been a great interest in development of this field of artificial intelligence and the research was quite limited [11]. It has changed in 1986, when D.E. Rumelhart et al. proposed the backpropagation training algorithm for feedforward ANNs [11]. Since then, ANN has been being considered as a useful forecasting tool.

One of the first neural predictive models was proposed by A. Lapedes and R. Farber in 1988 [12]. The researchers demonstrated that for certain applications neural networks can achieve significantly higher numerical accuracy than most of conventional techniques. As an example, dynamics in the Mackey-Glass equation was analyzed and it was proven, that there is no need for more than two hidden layers of neurons to solve most modeling and forecasting problems. Later on, A. S. Weigend et al. [13], focusing on real-world time series of limited record length, investigated the effectiveness of connectionist architecture for predicting the future behavior of nonlinear dynamical systems. The benchmark sunspot series were compared with chaotic data from a computational ecosystem. The thesis, that sigmoid networks trained with the weight-elimination algorithm outperform traditional nonlinear statistical techniques has been proven. Similar studies, where the relationship between dynamic systems and functional interpolation with ANNs had been discussed, have been performed by D. Lowe and A. R. Webb [14]. Comparable researches can be found in publications of D. Y. C. Chan and D. Prager, M. Cottrell et al., I. Ginzberg and D. Horn, I. Poli and R. D. Jones and B. E. Rosen [15–19]. J. Deppisch et al. proposed a new method for training of multilayer perceptrons to outputs of high precision [20]. The method was also applied to the prediction of chaotic systems and provided reduction of the absolute prediction error.

The available literature is very vast and there are many different applications of ANNs in forecasting problems. Among them, financial issues, as for example forecasting bankruptcy and business failure, foreign exchange rates and stock prices can be mentioned [21–26]. Another widely discussed in the literature application of neural networks is electric load consumption forecasting [27–30]. Among other forecasting problems that can be solved by ANNs energy yield from a photovoltaic installation [31,32], spare parts demand prediction [33,34] and even wind power issues [24,35] can be mentioned. In this article demand forecasting model based on ANNs has been proposed.

3. DEMAND FORECASTING MODEL BASED ON ARTIFICIAL NEURAL NETWORKS

Analysis of previously cited literature had become an inspiration for creating demand forecasting model based on artificial neural networks. The data from an international distribution enterprise has been taken into account and the model for "X" product volume forecasting has been prepared. All input parameters and output variable of the model were presented in Table 1.

Table 1 – Input parameters and output variable of the proposed neural forecasting model

Input parameters:		
x_1	–	period (week) code
x_2	–	sales value of the "X" product in the current period (week)
x_3	–	sales value of all group A's products in the current period (week)
x_4	–	sales value of all products in the current period (week)
x_5	–	total requirements of all regional distribution warehouses in the period *t-1*
x_6	–	the average sales volume of the product from the period *t-1* to the period *t-2*
x_7	–	the average sales volume of the product from the period *t-1* to the period *t-3*
x_8	–	the average sales volume of the product from the period *t-1* to the period *t-4*
Output variable:		
y	–	demand volume of the "X" product in the next period (*t+1*)

The demand volume level of each and every product largely depends on the demand volume levels that were earlier reported by local warehouses. In addition, the analysis results showed that the "X" product sales volume depends on the sales value of all products in the current period, and in particular those of assortment group A. In the research, the period code and the average sales volumes from two, three and four previous periods have also been used. In Table 2, the values of correlation coefficients between model parameters have been presented.

Table 2 – The values of correlation coefficients between model parameters

	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
y	1	0.118	0.698	0.750	0.596	0.790	0.158	0.190	0.241
x_1	0.118	1	0.196	0.212	0.238	0.114	0.226	0.300	0.348
x_2	0.698	0.196	1	0.963	0.887	0.494	0.086	0.114	0.148
x_3	0.750	0.212	0.963	1	0.875	0.555	0.094	0.128	0.173
x_4	0.596	0.238	0.887	0.875	1	0.416	0.212	0.217	0.217
x_5	0.790	0.114	0.494	0.555	0.416	1	0.171	0.215	0.252
x_6	0.158	0.226	0.086	0.094	0.212	0.171	1	0.867	0.768
x_7	0.190	0.300	0.114	0.128	0.217	0.215	0.867	1	0.913
x_8	0.241	0.348	0.148	0.173	0.217	0.252	0.768	0.913	1

The proposed three-layer network (Figure 1), the number $n = 4$ of hidden neurons was created using Matlab software. The choice of the network structure was based on trial-and-error testing of different structures on the number of hidden neurons containing in the range from 1 to 10. The network learning process was preceded by a data normalization in regard to minimum value.

There was 206 cases used in the network learning process from the period since 5th of September 2005 till 31st of December 2009. The data set has been divided into three subsets: training, validation and testing, respectively in the ratio of 60% – 20% – 20%. As a major criterion for assessing the quality of the model the value of the mean square error (MSE) has been selected. The functional sequence of network learning errors using Levenberg-Marquardt algorithm has been shown in Figure 2.

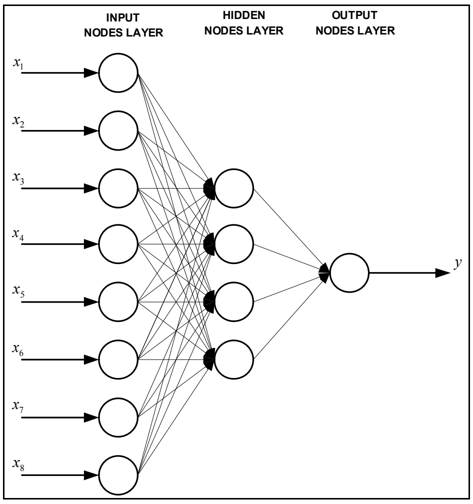


Figure 1 – Proposed neural network architecture

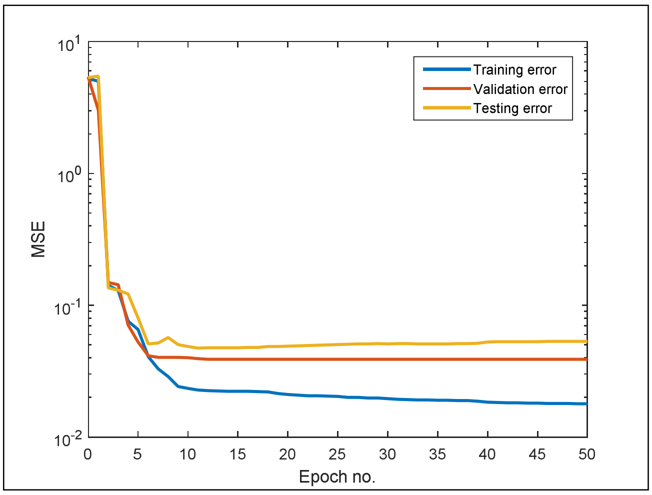


Figure 2 – Functional sequence of network learning errors

Network learning process was set up for 50 epochs. The process has not been interrupted, because the value of validation error reached the minimum value in the last epoch. In Table 3, the comparison of MSE error values for the considered neural network for different tested learning algorithms (available in Matlab) was presented. The MSE measure value is calculated according to Equation 1:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - y_i^*\right)^2 \qquad (1)$$

where:
n – number of observations,
y_i – observed value of the variable in the period i,
y_i^* – estimated value of the variable for the period i.

Table 3 – The comparison of MSE error values for the considered neural network for different tested learning algorithms

Matlab function	Learning algorithm name	Training error	Validation error	Testing error
trainlm	Levenberg-Marquardt	4 491	6 271	6 082
trainbfg	Quasi-Newton backpropagation	4 417	5 455	6 700
trainscg	Scaled conjugate gradient backpropagation	5 132	5 643	5 266
traincgf	Fletcher-Powell conjugate gradient backpropagation	4 904	5 877	5 615
trainoss	One step secant backpropagation	4 953	5 437	6 573
traincgp	Polak-Ribiére conjugate gradient backpropagation	5 104	5 143	5 500

As can be seen the lowest value of MSE error for the training set was obtained using Quasi-Newton backpropagation algorithm. However, for further analyzes, the network that uses Levenberg-Marquard algorithm has been chosen. The reason for choosing this algorithm were the results obtained during the next step of the network quality analysis – linear regression analysis. The analysis was carried out in relation to the entire data set and independently for training, validation and testing subsets. Figure 3 summarizes the results. Summary of statistical data for performed linear regression analysis is given in Table 4.

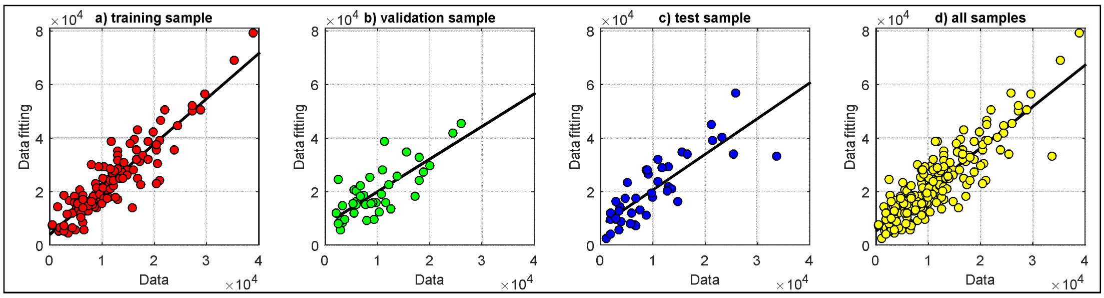


Figure 3 – Linear regression analysis

Table 4 – The comparison of MSE error values for the considered neural network for different tested learning algorithms

Statistics	Training sample	Validation sample	Testing sample	All data
Mean data MD	23 441	19 416	20 811	22 694
Standard Deviation SDD	13 261	9 603	12 363	12 464
Mean Error ME	12	-18	187	41
Standard Deviation of the Error SDE	5 850	8 670	7 810	6 870
Proportion SDE/SDD	0.44	0,90	0.64	0.55
Correlation R	0.91	0.77	0.83	0.88

The most important of the presented indicators for evaluation of the linear regression is the ratio of standard deviation of the errors SDE to standard deviation for SDD data. The values of this index take very high values, which indicate not very good regression abilities of the network and disqualify created model [36]. The next step was to compare obtained results with those of using conventional forecasting methods.

4. DEMAND FORECASTING WITH THE USAGE OF CONVENTIONAL FORECASTING METHODS

From many conventional forecasting methods, in the analyzed enterprise exponential smoothing methods and seasonal indices forecasting methods were used. For more details of conventional forecasting methods, readers are referred to [37–40].

Demand forecasts for product "X" by Brown's, Holt's and Winters' models as well as by seasonal indices method were presented in Figure 4. Except for MSE error value there has been calculated other quality measures (Table 5). The error values for each of used technique are provided in Table 6.

Table 5 – Ex post measures

Quality measure	Error function
Mean error	$ME = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - y_i^*\right)$
Mean absolut error	$MAE = \frac{1}{n}\sum_{i=1}^{n}\left\|y_i - y_i^*\right\|$
Root mean squared error	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - y_i^*\right)^2}$
Mean percentage error	$MPE = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i - y_i^*}{y_i}$
Mean absolut percentage error	$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left\|\frac{y_i - y_i^*}{y_i}\right\|$

Table 6 – Ex post measures values for forecasts obtained from using conventional forecasting methods

Forecasting method	Quality measure				
	ME	MAE	RMSE	MPE	MAPE
Brown's model	1 113	9 476	13 586	-229%	266%
Holt's model	119	9 893	14 086	-246%	281%
Winter's additive model	-308	1 0707	15 062	-263%	302%
Winter's multiplicative model	-41 204	4 7343	58 059	-1 399%	1 445%
Seasonal indices model	2 570	6 022	10 912	-117%	154%

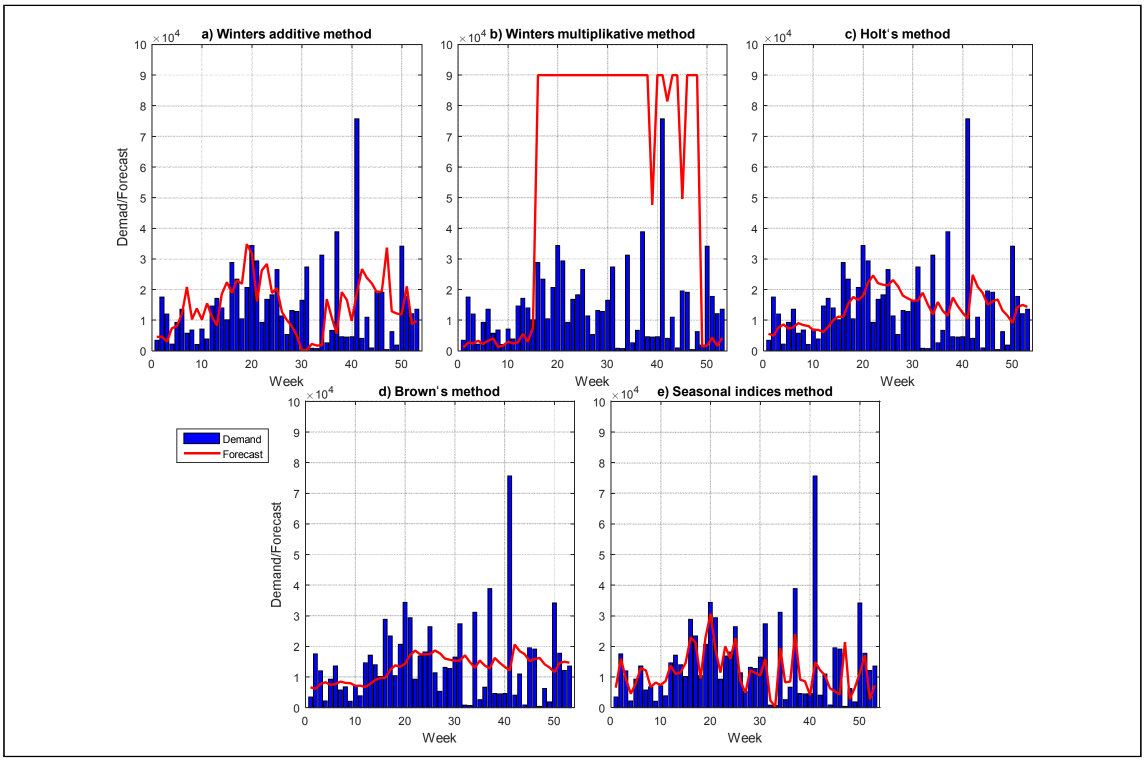


Figure 4 – Demand forecasts obtained from using conventional forecasting methods

5. COMPARISION OF OBTAINED RESULTS

Simulation studies have shown that the neural model allows for three times better performance compared to those given by the seasonal indices method (despite the fact that the resulting error values are still at an unacceptable level – Table 7). It can be assumed that inventory management models built on demand forecasting neural model will allow to achieve better results than models built on traditional forecasting methods.

Table 7 – MPE and MAPE measures values for forecasts obtained from using seasonal indices forecasting method and proposed artificial neural network based model

Forecasting method	**Quality measure**	
	MPE	MAPE
ANNs model	-50%	86%
Seasonal indices method	-229%	251%

In Figure 5, the comparison of demand forecasts for product "X" obtained by using those two methods is presented.

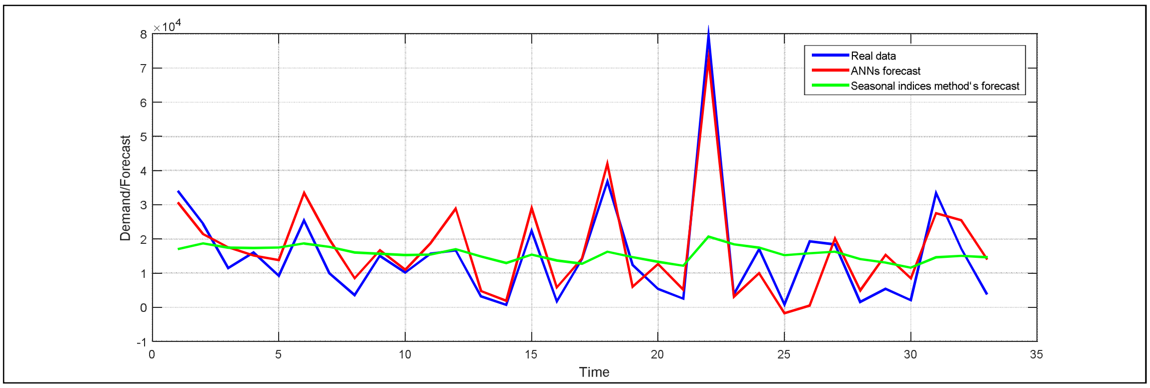


Figure 5 – Six-months' demand forecasts obtained from using proposed artificial neural network forecasting model and seasonal indices forecasting method

6. CONCLUSIONSAND FUTURE WORKS

The selection of appropriate inventory control method is influenced by such factors as customer service level, costs structure, order quantities, lead times, storage conditions and demand patterns. Construction of an appropriate inventory management system requires consideration of all listed parameters. In this work analysis only of one of those factors has been discussed – it was a demand pattern analysis using artificial neural networks forecasting model.

Proposed model helped to achieve better results than the conventional forecasting techniques. The results obtained make it, however, that the problem of establishing reliable sales forecasts at analyzed enterprise is still an open question.

Based on simulation results made on the built model, it can be concluded that artificial neural networks are of a great use in predicting economic phenomena and usually give better results than conventional methods. This factor encourages further research and analysis of the problem of inventory management in the analyzed enterprise. The analyses of all system components mentioned at the outset will allow to build an appropriate inventory control system in the company.

7. REFERENCES

[1] Feliks, J., Lenort R., Besta P.: *Model of multilayer artificial neural network for prediction of iron ore demand*, METAL 2011: 20th anniversary international conference on Metallurgy and materials, May 18th–20th 2011, Brno, Czech Republic, 2011, 1206–1210.

[2] Jurczyk, K., Karkula M.: *Selected aspects of spare parts inventory management*, CLC'2013: Carpathian Logistics Congress, December 9th–11th 2013, Cracow, Poland, Congress proceedings (reviewed version), TANGER Ltd., Ostrava, Czech Republic, 2014, 318–323.

[3] Kahraman, C., Yavuz M., Kaya I.: *Fuzzy and Grey Forecasting Techniques and Their Applications in Production Systems*, In: Kahraman, C., Yavuz, M. (Eds.) Production Engineering and Management under Fuzziness. Springer-Verlag, Berlin, Heidelberg, 2010, 1–24.

[4] Karkula, M., Jurczyk K., Bukowski L.: *Nondeterministic factors in simulation models of logistics processes*, CLC'2012: Carpathian Logistics Congress, November 7th–9th 2012, Jasenik, Czech Republic, Congress proceedings (reviewed version), TANGER Ltd., Ostrava, Czech Republic, 2013, 529–535.

[5] Lenort, R., Feliks, J., Stas D.: *Forecasting the consumption of plates in plants producing heavy plate cut shapes*, METAL 2010: 19th international metallurgical and materials conference, May 18th–20th 2010, Roznov pod Radhostem, Czech Republic, 2010, 214–218.

[6] Samolejová, A., Feliks J., Lenort R., Besta P.: *A hybrid decision support system for iron ore supply*, Metalurgija 51/1 (2012), 91–93.

[7] Zhang, G.P.: *Time series forecasting using a hybrid ARIMA and neural network model*, Neurocomputing, 50 (2003), 159–175.

[8] Zhang, G., Patuwo E.B., Hu M.Y.: *Forecasting with artificial neural networks: The state of the art*, International Journal of Forecasting, 14 (1998), 35–62.

[9] McCulloch, W.S., Pitts W.: *A Logical Calculus of Ideas Immanent in Nervous Activity*, Bulletin of Mathematical Biophysics, 5 (1943), 115–133.

[10] Hu, M.J.C.: *Application of the adaline system to weather forecasting*, Master thesis, Technical Report 6775-1, Stanford Electronic Laboratories, Stanford, CA, June 1964.

[11] Rumelhart, D.E., Hinton G.E., Williams R.J.: *Learning internal representations by error propagation*, In: Rumelhart, D. E., McClelland, J. L. (Eds.), Parallel Distributed Processing, MIT Press, Cambridge, 1986.

[12] Lapedes, A., Farber R.: *How neural nets work*, In: Anderson, D. Z. (Eds.), Neural Information Processing Systems, American Institute of Physics, New York, 1988, 442–456.

[13] Weigend, A.S., Huberman B.A., Rumelhart D.E.: *Predicting the future: A connectionist approach*, International Journal of Neural Systems, 1/3 (1990), 193–209.

[14] Lowe, D., Webb A.R.: *Time series prediction by adaptive networks: A dynamical system perspective*, IEE proceedings F – Radar and Signal Processing, 138/1 (1991), 17–24.

[15] Chan, D.Y.C., Prager D.: *Analysis of time series by neural networks*, IEEE International Joint Conference on Neural Networks, 1 (1991), 355–360.

[16] Cottrell, M., Girard B., Girard Y., Mangeas M., Muller C.: *Neural modeling for time series: A statistical stepwise method for weight elimination*, IEEE Transactions on Neural Networks, 6/ 6 (1995), 1355–1364.

[17] Ginzberg, I., Horn D.: *Learning the rule of a time series*, International Journal of neural Systems, 3/167 (1992), 167–177.

[18] Poli, I., Jones R.D.: *A neural net model for prediction*, Journal of the American Statistical Association, 89/ 425 (1994), 117–121.

[19] Rosen B.E.: *Neural network moving averages for time series prediction*, Proceedings of the SPIE: Science of Artificial Neural Networks, vol. 1966(1993), 448–456.

[20] Deppisch, J., Bauer H.-U., Geisel T.: *Hierarchical training of neural networks and prediction of chaotic time series*, Physics Letters A, 158/1–2 (1991), 57–62.

[21] Azoff, E.M.: Neural Network Time Series Forecasting of Financial Markets, John Wiley and Sons, Chichester, 1994.

[22] Gent, C.R., Sheppard, C.P.: *Predicting time series by a fully connected neural network trained by back propagation*, Computing and Control Engineering Journal 3/3 (1992), 109–112.

[23] Khashei, M., Bijari M.: Fuzzy artificial neural network (p, d, q) model for incomplete financial time series forecasting, Journal of Intelligent & Fuzzy Systems, 26/2 (2014), 831–845.

[24] Refenes, A.-P.: *Neural Networks in the Capital Markets*, John Wiley & Sons, New York 1995.

[25] Wang, J., Wang J., Fang W., Niu H.: *Financial Time Series Prediction Using Elman Recurrent Random Neural Networks*, Computational Intelligence & Neuroscience, 2016 (2016), 1–14.

[26] Zafeiriou, T., Kalles D.: *Short-term Trend Prediction of Foreign Exchange Rates with a Neural-Network based Ensemble of Financial Technical Indicators*, International Journal on Artificial Intelligence Tools, 22/3 (2013), 1–13.

[27] Baliyan, A., Gaurav K., Mishra S.K.: *Review of Short Term Load Forecasting using Artificial Neural Network Models*, International Conference on Intelligent Computing, Communication & Convergence ICC-2015, Procedia Computer Science 48 (2015), 121–125.

[28] Ilić, S.A., Vukmirović S.M., Erdeljan A.M., Kulić F.J.: *Hybrid Artificial Neural Network System for Short-Term Load Forecasting*, Thermal Science, Vol. 16, Supplement, 2012, s215–s224.

[29] Li-Guo, C., Hsiao-Dong C., Na D., Rong-Peng L.: *Group-based chaos genetic algorithm and non-linear ensemble of neural networks for short-term load forecasting*, IET Generation, Transmission & Distribution, 10/6 (2016), 1440–1447.

[30] Rana, M., Koprinska I.: *Forecasting electricity load with advanced wavelet neural networks*, Neurocomputing, Vol. 182, March 2016, 118–132.

[31] Dolara, A., Grimaccia F., Leva S., Mussetta M., Ogliari E.: *A Physical Hybrid Artificial Neural Network for Short Term Forecasting of PV Plant Power Output*, Energies, 8(2)(2015), 1138–1153.

[32] Jurasz, J., Zakrzewski M.: *Application of Artificial Neural Networks (ANN) for forecasting energy yield from a photovoltaic (pv) installation*, Logistyka, 4(2015), 9068–9075.

[33] Li, S.G., Kuo X.: *The inventory management system for automobile spare parts in a central warehouse*, Expert Systems with Applications, 34(2008), 1144–1153.

[34] Sharma, R., Garg S.: *Spare parts management at automobile service centre using artificial neural network*, International Journal of Services, Economics and Management, 4– 2, 2012, 122–144.

[35] Li, T., Li Y., Liao M., Wang W., Zeng C.: *A New Wind Power Forecasting Approach Based on Conjugated Gradient Neural Network*, Mathematical Problems in Engineering, 5/31/2016, 1–8.

[36] Karkula, M.: *Modelowanie i symulacja złożonych procesów logistycznych o charakterze dyskretno-ciągłym na przykładzie Elektrociepłowni Kraków SA*, PhD disertation, AGH, Faculty of Management, Cracow 2007.

[37] Box, G.E.P., Jenkins G.M.: *Time Series Analysis: Forecasting and Contol*, Holden-Day, San Francisco, California, USA, 1976.

[38] Brown, R. G.: *Statistical Forecasting for Inventory Control*, McGraw-Hill, New York 1959.

[39] Zhang, G.P.: *Time series forecasting using a hybrid ARIMA and neural network model*, Neurocomputing, 50 (2003), 159–175.

[40] Winters, P.R.: *General Exponential forecasting: A Computer Program for the IBM 360*, ONR Research Memorandum No. 71/1960.

DOES SCHEDULING REALLY HAVE AN IMPACT ON MACHINE UTILISATION IN FLOW SHOP SYSTEMS?

Waldemar KACZMARCZYK[1]

[1]AGH University of Science and Technology
Department of Operations Research and Information Technology
al. Mickiewicza 30, 30-059 Kraków,
Poland

Abstract:

The machine utilisation remains one of the most important objectives of the production planning and scheduling. Although utilisation is a characteristics of a long term stochastic process and the makespan describes only a single deterministic schedule, in production scheduling models maximization of utilisation is usually approximated by makespan minimization. Presented analysis of typical production planning system and experimental results show that in permutation flow shop systems with unlimited buffers the impact of makespan minimization on long-term machine utilisation might be significantly overestimated. To bridge this gap between theory and practice a new measure of quality considering multiple schedules is proposed.

Keywords:

production, scheduling, machine utilisation

1. INTRODUCTION

Machine utilisation remains an important objective in production planning. In the queueing theory utilisation is defined as the ratio of the arrival rate and the production rate of orders and in production systems as the ratio of the throughput or workload and the capacity [1,2]. In both cases utilisation is a characteristics of a *long term stochastic process*.

In scheduling theory utilisation is estimated for single, deterministic schedules and is defined as *the ratio of the sum of the time instances a machine is active to the elapsed time* [3]. This definition is ambiguous for systems with multiple machines and computationally expensive. Therefore *in most (...) studies, the makespan objective is used instead of utilisation* [3], i.e. maximal completion time of all operations. Despite the fact that makespan ignores the capacity, i.e. period length, most researchers believe that *clearly, there is a close correspondence between utilisation and makespan in a completed schedule* [3].

Dudek et al [4] believe that makespan minimization in flows shop system has no practical significance because there are no practical applications of this model. But their review was made only for the classic flow shop problem proposed in 1954 by Johnson [5] and ignored the indirect relationship between makespan and utilisation. According the 2nd edition of book by Hopp and Sperarman [1] *most manufacturing settings have jobs entering the system continually, so the issue of how to schedule a fixed number of jobs to minimize makespan is not relevant*. However in their opinion presented already in the 3rd edition of the same book [2]: *A measure that is closely related to utilisation is makespan, which is defined as time it takes to finish a fixed* *number of jobs. For this set of jobs, the production rate is the number of jobs divided by the makespan, and the utilisation is the production rate divided by capacity.*

In this paper the impact of scheduling, makespan minimization, on machine utilisation is estimated in two types of systems, static and dynamic. In the static system, schedules in consecutive periods of time, shifts, days or weeks, are treated separately. If the makespan is longer than the period length, the backlog is processed in overtime. This way schedules in consecutive periods are independent.

In the dynamic system, if the makespan is longer than the period length schedules overlap, i.e. unfinished operations from one period constitute initial workload for the next period. This second system considers the case of jobs entering the system continually as mentioned by Hopp and Sperarman [1].

In Section 2 basic definitions and relationships are introduced. In Section 3 the data set is described. In Sections 4 and 5 results of experiments are presented respectively for the static and dynamic system. In Section 6 conclusions are formulated.

2. MAKESPAN AND UTILISATION IN PRODUCTION PLANNING

It is hard to find anything about makespan or utilisation in classic books describing the standard production planning system MRPII, e.g. [6,7]. One reason is that MRPII has no clearly defined optimisation objectives, but another that neither makespan nor utilisation are explicitly used in the planning process. Therefore it is necessary to explain their role in the overall planning process.

In a typical production planning process, one can distinguish two steps. In the first step, one have to allocate the whole independent and dependent demand to periods, i.e. to determine production volume x_t in all periods t, so that all due dates are met and that machines workload W_t does not exceed capacity $W_{\max}$ in any period:

$$W_t(x_t) \le W_{\max} = \eta L \tag{1}$$

The workload W_t is a function of production volume x_t and the capacity $W_{\max}$, i.e. the maximal acceptable workload, is equal to product of the period length L and *the assumed (planned) utilisation* η. This utilisation η is in practice determined by comparison of the time available for production and production throughput, i.e. capacity demonstrated by the system in the past [7]. For the purpose of experiments with scheduling algorithms one can assume that the capacity is equal to the period length L and the utilisation η is smaller than 100% only because of schedules unavoidable imperfection we want to measure. Let us ignore other causes of machine downtimes like machine failures, tool or product defects, material shortages etc.

The second step of the production planning is scheduling of production orders on machines within a single period, i.e. sequencing and timing of all operations with respect to limited resources. If assignment of production volumes x_t to periods t satisfies all customer due date requirements the only objective of production control may be to execute all production orders within limits of chosen period, i.e. to minimize the makespan.

Common sense suggests that minimizing makespan allows to assign more workload to periods and therefore ensures higher machine utilisation. This hypothesis is verified in the following sections.

3. EXPERIMENT DESIGN

Experiments have been conducted for a permutation flow shop system with unlimited buffers, 5 machines and 20 jobs, for 1000 different instances (production periods) of randomly generated non-zero processing times. In every period (instance) processing time of every operation was randomly generated from the same range. Therefore the bottleneck is moving period by period, i.e. in every period another machine may constitute the bottleneck. At the end processing times were rescaled so that the workload of the bottleneck machine W_{max} is the same in all periods. An average workload of machines over all periods (instances) is equal to respectively 86%, 93%, 85%, 88% and 91% of the bottleneck workload W_{max}.

In real system for given period length L, managers first set assumed (planned) utilisation η and then calculate the maximal acceptable workload $W_{max} = \eta L$. In described experiments at first the bottleneck workload W_{max} was chosen in an arbitrary way, as a guideline for processing times generator, next the assumed utilisation η was set and finally the period length was calculated $L = W_{max} / \eta$.

In the dynamic system, after scheduling of all operations in period t, the initial workload $r_i(t+1)$ of machine i in period $t+1$ was calculated, i.e. the backlog from period t, as the non-negative difference between maximal completion time $C_{ij}(t)$ among all operations j on machine i and the period length:

$$r_i(t+1) = \max\{0, \max_j C_{ij}(t) - L\} \quad (2)$$

4. STATIC SYSTEM

In static system schedules in consecutive periods are independent, i.e. the backlog is ignored, e.g. thanks to overtime. Usually only the average makespan C_{max} is considered. To calculate the utilisation of bottleneck machine U_{max} one have to divide bottlenecks workload W_{max} by the actual makespan. If assumed utilisation η is equal to the average bottleneck utilisation then almost 50% of schedules will be too long, i.e. completed after the end of the period. Managers would prefer to know the value of assumed utilisation for which they have some probability, let say 0.95, that the schedule makespan will not exceed the period length, i.e. 0.95 percentile $P_{0.95}$ of makespan distribution. All results are presented in Table 1, Δ present the relative distance to the best result, i.e. relative quality.

Table 1 – Results for the static system

	C_{max} / W_{max}		U_{max}	
Algorithm	*Avg.*	Δ[%]	$P_{0.95}$	Δ[%]
Taillard	1.047	0.0	92.1	0.0
NEH	1.075	2.8	87.5	4.6
Palmer	1.180	13.3	78.3	13.8
Random	1.245	19.8	73.1	19.0

Taillard Taboo Search heuristics [8] ensures suboptimal solutions, i.e. newer algorithms improve rather computation time than solution quality [9]. NEH algorithm proposed by Nawaz et al [10] is a very good constructive heuristics, while Palmer heuristics [11] is rather naive extension of the Johnson principle [5] and does not ensure a good quality solutions. Finally a solution with random job sequence was calculated.

Quality of makespan and utilisation in Table 1 are very similar. This means that in the static system makespan well approximates utilisation.

5. DYNAMIC SYSTEM

In Figure 1. presented are two flows shop schedules for the same data set which differ only in job sequence: in a) a short schedule, i.e. with short makespan, and in b) a long schedule. In both schedules all operations are started as late as possible, i.e. without delaying the last operation on every machine.

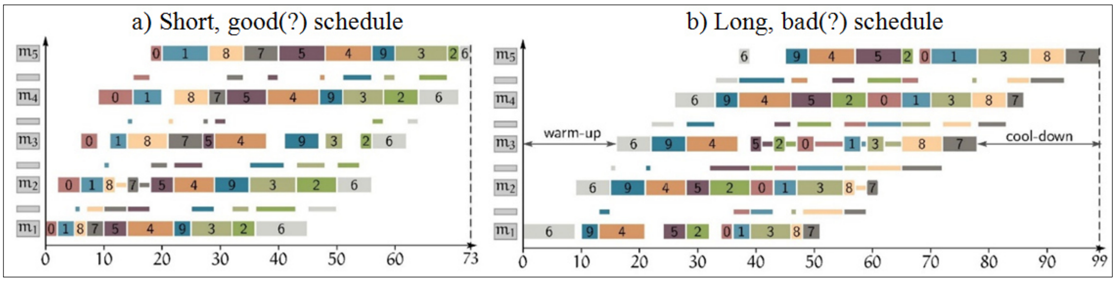


Figure 1 – Short and long schedules of a permutation flows shop

In both charts breaks on all machines are seldom and short. In the worse solution the bottleneck machine M4 makes no breaks! They differ only in long warm-up and cool-down periods. Long warm-up and cool-down times of the long schedule could be however utilised by overlapping with neighbour schedules.

Figure 2. illustrates the schedule overlapping concept. Two schedules are repeated three times, a short and a long one. Both schedules are determined for the same set of jobs but reversed order. For both machines the total workload is equal to 5 units of time. Makespan of the short schedule has 6 units of time and the long one 9. Compare charts a) and b).

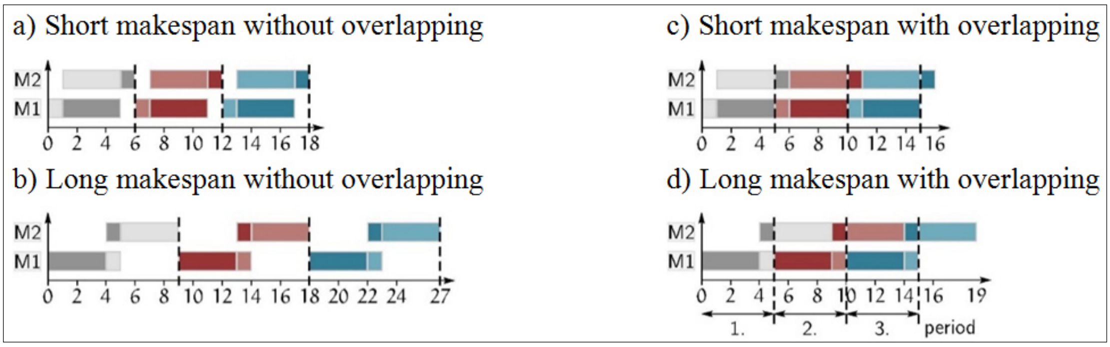


Figure 2 – Multi-period schedules

In all charts these two schedules are repeated in three separate periods of time. In figures a) and b) schedules do not overlap, i.e. whole schedules are executed during separate periods. In figures c) and d) schedules in consecutive periods overlap, i.e. the cooldown time of a schedule is timed already during the next period, i.e. operations of machine M2 unfinished in one period constitute *initial workload* for the next period. Without overlapping period length has to be longer than the makespan to finish it on time, i.e. the utilisation of machines is smaller for bad schedule with longer makespan than for the good schedule, 5/6 against 5/9. However if overlapping is allowed the period length is might be the same in both cases, i.e. 5 units of time, and utilisation of both machines is then 100%.

In dynamic system operations unfished in period t constitute initial workload $r_i(t+1)$ in period t+1, i.e. machine ready times (1). This way schedule from period t has an impact on schedule in the next period. To evaluate utilisation in such dynamic system schedules in 1000 consecutive periods have been calculated for the same data set as for the static system.

Figure 3 presented are values of the makespan in first 200 periods for assumed (planned) utilisation equal to 103%, i.e. the period length L was equal to $W_{max}/1.03$. To make it more readable in chart presented are relative values of makespan $C_{max}(t)/W_{max}$, i.e. absolute makespan values divided by maximal workload. In chart presented are also with trend lines computed with the least-squares regression method.

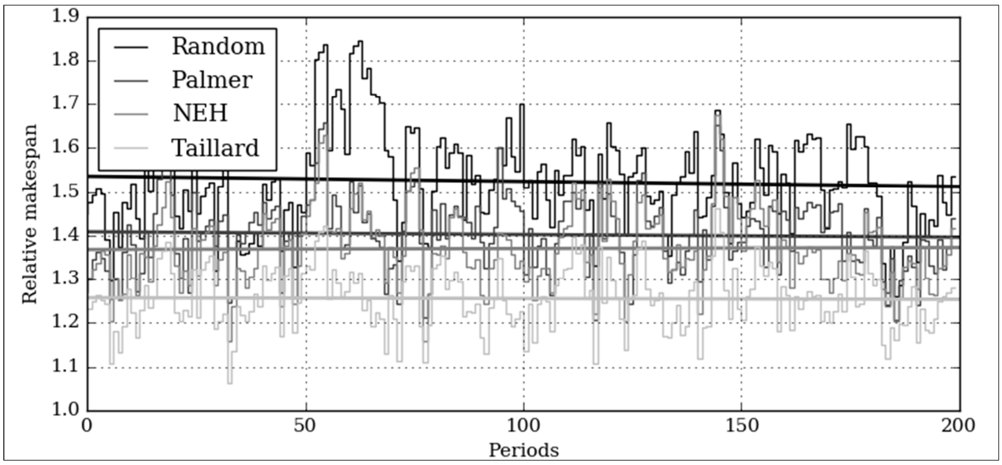


Figure 3 – Relative makespan $C_{max}(t)/W_{max}$ with trend line in dynamic system for assumed bottleneck utilisation η = 103%

Important are three observations. First, makespan fluctuations period by period are very strong for all methods. Second, independent of scheduling method the trend line is strictly horizontal, i.e. the backlog does not increase. Third, average makespan, and backlog, are short for good algorithms, and long for bad algorithms.

Additional comment is necessary to the value of assumed utilisation. How is it possible to produce without increasing backlog a workload higher than 100% of the capacity, i.e with machine utilisation higher than 100%? That's easy. Assumed utilisation is related in every period to the bottleneck machine and in every period the bottleneck constitutes another machine. So the real machine utilisation is smaller than 100%. For assumed bottleneck utilisation η = 103% average real utilisation of machines was respectively 89%, 96%, 88%, 90% and 94%, independent of the scheduling algorithm.

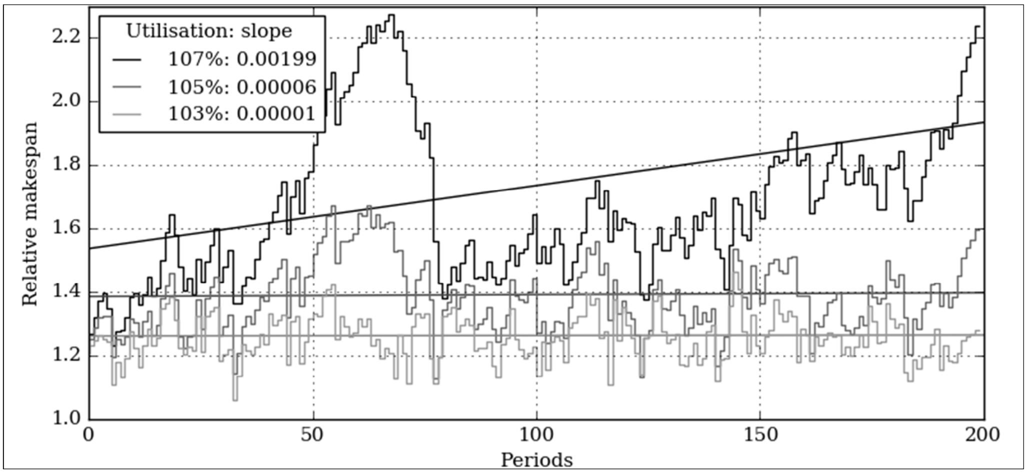


Figure 4 – Relative makespan $C_{max}(t)/W_{max}$ with trend line in dynamic system for Taillard heuristic

In Figure 4 one can see what happens when assumed bottleneck utilisation η is increased. For *η* = 105% the process is still stable, i.e. the slope of the trend line is equal to 0.00006, what means that the makespan values increase only by 0.6% in 100 periods. For 107% the makespan increases by 19% per 100 periods. Increment of makespan leads to similar makespan of backlog. Such increment would be inacceptable in any company.

The idea of new utilisation measure that could replace the makespan is to determine maximal assumed bottleneck utilisation for which the process is stable, i.e. the slope parameter of the trend line is small enough. In Figure 5 presented are slope parameters for increasing assumed bottleneck utilisation *η*.

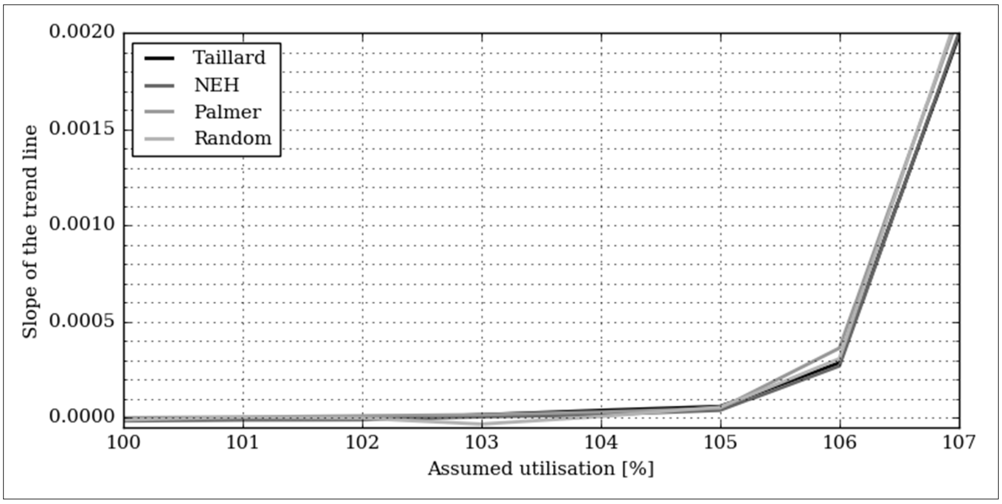


Figure 5 – Slope of the trend line of relative makespan $C_{max}(t)/W_{max}$ in dynamic system

For all algorithms up to *η* = 105% the slope is smaller than 0.0001, i.e. 1% of makespan increment per 100 periods. For *η* = 106% it is about 3% increment, and for *η* = 105% the increment value peaks to 20%.

6. CONCLUSIONS

In this paper considered is permutation flow shop systems with unlimited buffers. In static system, where given schedule does not have any impact the next schedule, and therefore schedules are analysed independently the makespan well approximates machine utilisation. In dynamic system, where unfished operations from one period, constitute initial workload for the next period, i.e. schedules overlap, minimizing makespan has impact only on the average backlog, i.e. the overlapping period, but not on the machine utilisation.

7. ACKNOWLEDGMENTS

This work has been supported by NCN research grant #DEC-2013/11/B/ST8/04458, and by AGH.

8. REFERENCES

[1] Hopp, W.J., Spearman M.L.: *Factory Physics*, McGraw-Hill, Boston, 2nd ed., 2000.

[2] Hopp, W.J., Spearman, M.L.: *Factory Physics*, McGraw-Hill, Boston, 3rd ed., 2008.

[3] Pinedo M.L.: Scheduling, Theory, Algorithms, and Systems, Springer, Berlin, 2008.

[4] Dudek, R.A., Panwalkar S.S., Smith M.L.: *The Lessons of Flowshop Scheduling Research*, Operations Research 40(1)(1992), 7–13.

[5] Johnson, S.M: *Optimal Two- and Three-Stage Production Schedules with Setup Times Included*, Naval Research Logistics Quarterly 1(1954), 61–68.

[6] Silver, E.A., Pyke D.F., Peterson R.: *Inventory Management and Production Planning and Scheduling*, Wiley, 1998.

[7] Proud, J.F., *Master Scheduling: A Practical Guide to Competitive Manufacturing*, Wiley, Hoboken, New Jersey, 2007.

[8] Taillard, É.D.: *Some efficient heuristic methods for the flow shop sequencing problem*, European Journal of Operational Research, 47(1)(1990), 65–74.

[9] Nowicki, E., Smutnicki C.: *A fast tabu search algorithm for the permutation flow-shop problem*, European Journal of Operational Research, 91(1)(1996), 160–175.

[10] Nawaz, M., Enscore Jr. E. , Ham I.: *A Heuristic Algorithm for the m- Machine, n-Job Flow-shop Sequencing Problem*, OMEGA The Int. J. of Mgmt Sci., 11(1)(1983), 91–95.

[11] Palmer, D.S.: *Sequencing Jobs Through a Multi-Stage Process in The Minimum Total Time – A Quick Method of Obtaining a Near Optimum*, Operations Research Quarterly, 16(1965), 101–107.

CONTROL SHARING ANALYSIS AND SIMULATION

Maksymilian KOŁODZIEJ[1], Izabella STACH[2]

[1]maksymilian.kolodziej@gmail.com
Krakow, Poland
[2]AGH University of Science and Technology, Faculty of Management
Al. Mickiewicza 30, 30-059 Krakow,
Poland

Abstract:

This paper is devoted to financial and economic modeling and, in particular, to indirect control in corporate shareholding structures. Since shareholding size does not actually reflect an investor's power-control in corporate shareholding networks, diverse approaches to measuring the control-power of investors were proposed. This paper focuses in particular on the model of Denti and Prati [1] and its implementation to power-control sharing analysis and simulation in real shareholding structures thanks to the computer program "Control Sharing Simulation".

Keywords:

financial and economic modeling, corporate analysis, indirect control, game theory, power indices

1. INTRODUCTION

This paper focuses on indirect control in corporate shareholding structures. This topic is important in financial economics, but it is not easily modeled. In corporate shareholding networks, determining who has the power within a stock corporate company might be a very complex problem. Therefore, it is important to know the coalitions of firms that may exert control over a specific company or minimal coalitions (in size) that can control all companies in a closed shareholding network. Moreover, the size of shares held in the company does not actually reflect an investor's power-control. Of course, control/power that an investor can have over a certain firm is related to the percentage of shares that he/she owns, but also depends on other factors. Namely, a shareholder can have significantly more or less corporate control-power than the percentage of shareholding rights can reflect. In [2], an example of a company with three shareholders is given that reflects this problem. Namely, if the distribution of voting rights in a company among shareholders 1, 2, and 3 is 70%, 20%, and 10%, respectively, then, taking into account only shareholding size, it would appear that the degree of control-power for the each of the three investors is in proportion to the percentage of their voting rights. But in practice, the second and third shareholders are powerless under, a simple majority-rule voting system. The first shareholder is, of course, a "dictator" if the voting system does not require a greater than 70% majority of voting rights in making the important decisions. In other words, shareholder 1 controls all outcomes of the corporate decisions. Thus, shareholding size does not reflect the actual power distribution in the shareholding structures. In 1954, Shapley and Shubik [3] identified a successful implementation of power indices – cooperative game theory instruments – to measurement the control/power in corporate networks; see also [4].

In the context of game theory, various approaches were proposed to model the corporate shareholding relations and measure the indirect power of the firms involved in corporate shareholding networks. One rather pioneering one was the approach introduced by Gambarelli and Owen in 1994; see [5]. Since then, numerous other approaches have been proposed. For example, in [6,7,8,9], a reader can find a good and broad literature review of the most relevant references in this topic. The most recent approaches, which are based on the use of power indices to model control relationships in corporate structures, are those of Bajuri et al. [2], Crama and Leruth [6,7], Karos and Peters [8], and Mercik and Łobos [10].

This paper concentrates in particular on the model of Denti and Prati [1]. In [1,11] (and also Gambarelli and Owen in [5]), the authors focused on determining the winning coalitions of firms in a controlling structure. The purpose of this paper is the implementation of the Denti and Prati approach to power-control sharing analysis in a real-word shareholding structure and to provide some simulation thanks to the computer program "Control Sharing Simulation" elaborated by Kołodziej [12] within in scope of his master's thesis.

This paper is organized as follows. In Section 2, we provide some game-theoretical notation and preliminary definitions that are necessary for understanding the approach of Denti and Prati. In Section 3, we present two real-word examples of corporate shareholding networks. Section 4 presents the Denti and Prati approach. Section 5 is devoted to the computer program "Control Sharing Simulation." In Section 6, some simulations are provided applying the Denti and Prati approach to the examples described in Section 3. Finally, Section 7 concludes with some observations.

2. PRELIMINARY DEFINITIONS

As we mentioned in the previous section, game-theoretical approaches use power indices in order to measure control in corporate networks. In such approaches, shareholders are interpreted as players in a simple game (particularly, in a weighted majority game). Hereafter, we provide some game-theoretical preliminary notation and definitions necessary to better understand the model presented in Section 4.

Recall that a game is a set of rules describing strategic decision-making. In the cooperative games, players can come together in order to obtain common advantages. Thus, in cooperative games, binding agreements are possible before the start of the game. Let $N = \{1, 2, \ldots, n\}$ be a finite set of players. Any subset S of N is called a *coalition*. The set of all coalitions is denoted by 2^N. Formally, a *cooperative game* consists of two elements: (i) a set of players N; and (ii) a real-valued function $v : 2^N \to R$, called the *characteristic function* of the game, that associates with every coalition $S \subseteq N$, a number $v(S)$ called the *worth* of coalition S in the game v and satisfies the following condition: $v(\emptyset) = 0$. A *simple game v* on N is the game in which v takes values from set $\{0, 1\}$ and fulfils the condition $v(T) \le v(S)$ whenever $T \subseteq S$. Coalition S is called *winning* if $v(S) = 1$, and *losing* otherwise (i.e., if $v(S) = 0$). By $W(v)$, or just W, we denote the collection of all winning coalitions in game v. Player i is *critical* in winning coalition S if S is winning with I and losing without i. A *minimal winning coalition* is a winning coalition with all players who are critical. By $W^m(v)$ (or simply W^m), we denote a set of all minimal winning coalitions in v. Either W or W^m determines the game. A *weighted majority game* is a simple game in which weight w_i (for instance, the percentage of voting rights) is assigned to each player i, and a coalition is winning when the sum of the weights of each coalition member is superior to a majority quota q (for instance, 50% of the simple majority rule). Formally, in a weighted majority game, S is winning if $w(S) = \sum_{i \in S} w_i > q$. A *power index* for simply games is a mapping *f* that assigns to any simple game *v* vector $f(v) = (f_1(v), f_2(v), \dots, f_n(v))$, where the real number $f_i(v)$ is the power of player *i* in the game *v*. In relation to corporate shareholding structures, we can quote Crama and Leruth (see [5]) that "power indices are expected to reflect the relative capacity of each shareholder (be it a firm or an individual) to impose its will to a target company, measured either by its ability to form coalitions with other shareholders to win a vote, or by its ability to change the final outcome of a vote by swinging its own vote."

3. EXAMPLES OF CORPORATE NETWORKS

Each complex shareholding structure may be represented in two compact ways: by a directed graph (e.g., Figure 1 or 2) or by $n \times n$ matrix (e.g., Table 1) such that the value at place (*i, j*) represents the percentage of stocks of firm *j* owned by firm *i*. Figure 2 shows a shareholding network with cross-holdings corresponding to cycles in the graph.

Figure 1 presents the simplified organization chart of the Porsche-Volkswagen corporate structure (from 2008 to 2013) considered in [8]. The players are: Porsche Family (1), Qatar (2), Lower Saxony (3), Porsche SE (4), Volkswagen AG (5), Porsche AG (6), and Others (7). Let us consider this case with majority quota q = 80%. In this case, we have seven players, where four of which (1, 2, 3, 7) are investors and three (4, 5, 6) are stock companies.

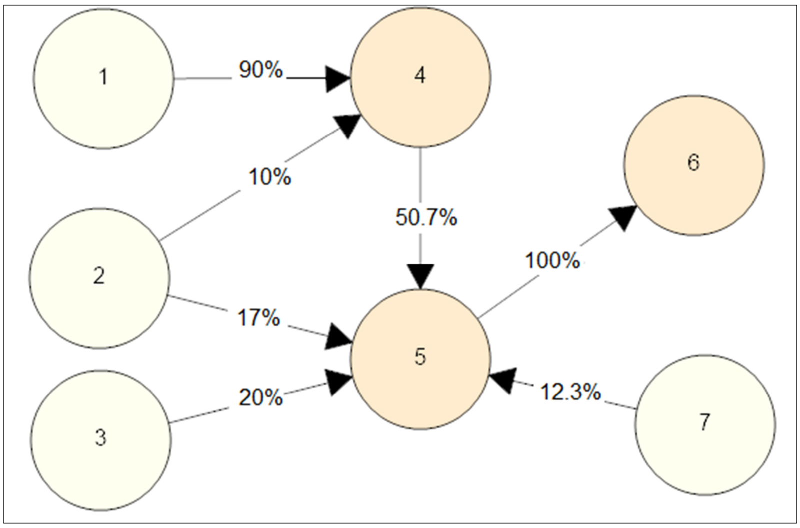


Figure 1 – A shareholding structure of the Porsche-Volkswagen case

We will use the Porsche-Volkswagen case to provide some analyses and simulation, taking into account both the Denti and Prati approach and computer program "Control Sharing Simulation" (see Section 6).

Figure 2 presents an example of a corporate cyclic network. This example was considered in [10] and refers to the Speiser and Baker case. In this network, there are six players, and four of which are investors. Namely, there are the following players: Medallion (1), Speiser (2), HealthMed (3), HealthChem (4), Baker (5), and Others (6). For this case, we consider simple majority quota q = 50%.

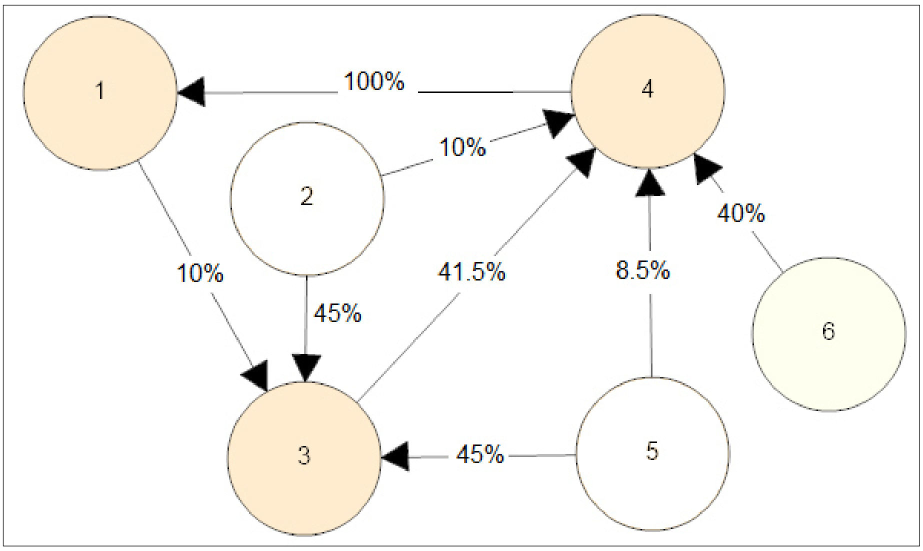


Figure 2 – A shareholding structure of the Speiser-Baker case

4. DENTI AND PRATI APPROACH

In [1], Denti and Prati proposed an algorithm to find all of the winning coalitions in the corporate network of a given firm. They assumed that the number of direct and indirect shareholders is finite. Giving the set of all direct and indirect shareholders of a firm, the proposed algorithm is able to discover whether coalition *S* is winning or not in any so-called formal game system (collection of weighted majority games). Denti and Prati do not limit the alliances able to achieve control of the target company solely to coalitions of only investors, like in the models of Gambarelli and Owen [5] and Crama and Leruth [6,7], for example. Here, the winning coalitions can be composed either of investors or stock companies.

The Denti and Prati algorithm has exponential computational complexity; thus, the problem with computation can arise if the number of firms is large. This model was then extended in [11] in order to suitably classify the winning coalitions and calculate all of the coalitions of all relevance. In this paper, we consider only the model from [1]. For a detailed description of the Denti and Prati algorithm, see [1]. Of course, in order to apply the Denti and Prati model (or other game-theoretical approaches mentioned in this paper), direct control relations must be retrieved from the data.

Denti and Prati did not consider power indices in their approach; but having the set of all winning coalitions (or all minimal winning coalitions) is sufficient to determine a game. Thus, power indices can be applied to measure the control power of firms in a corporate shareholding structure.

5. COMPUTER PROGRAM "CONTROL SHARING SIMULATION"

The lack of appropriate software greatly reduces the practical applications of the approaches to modeling and calculating indirect control proposed in the literature. Thus, Kołodziej [12] proposed the "Control Sharing Simulation" program. "Control Sharing Simulation" is a computer program where the main task is to calculate and illustrate the level of control that firms exercised over other companies in either acyclic or cyclic corporate networks. This knowledge can be useful for competing companies or for predicting events that may arise in financial markets, for example.

In particular, the "Control Sharing Simulation" program allows us to quickly and transparently create graphs, read and save graphs to files, and run the so-called "graphical algorithm" which clearly illustrates the degree of control of a preset coalition of firms on the rest of the companies.

In order to run the Denti and Prati algorithm (or graphical algorithm), the user has to select at least one company for which he/she is interested in knowing which coalitions of firms that can exert control over it. After running the algorithm, detailed calculations appear on the screen; so, it is possible to trace the steps of the Denti and Prati algorithm. The program not only enables to perform the algorithm of Denti and Prati (i.e., finding all winning coalitions in certain company), but it is also able to find the set of all minimal winning coalitions (a considerable improvement to the algorithm). To sum up: for a given corporate network, the program allows us to perform a simulation that is able to:

- create a direct graph and the corresponding matrix representation of direct ownership
- find all minimal winning coalitions that control a preset coalition of firms
- find all winning coalitions that control a preset coalition of firms
- check whether a certain coalition of firms is able to control a preset coalition of firms or not
- illustrate via graphics the degree of control of the chosen coalition of firms on the rest of companies

In the application "Control Sharing Information", a number of helpful tools were implemented to facilitate the creation of graphs and calculate indirect control. To run the program requires at least Windows XP, Windows Vista, or Windows 7 (or higher) installed together with of the .NET framework version (at least 4.0) or Linux operating system and an application compiled in Mono runtime (at least version 2.8). The following technologies and tools have been used to implement the project: Visual Studio 2010, programming language C #, NET framework version 4.0, Library to display graphs – Piccolo20, XML.

6. SOME SIMULATIONS

In this section, we perform some simulations that take into account the Denty and Prati algorithm and the two real-world corporate shareholding structures presented in Section 3. The simulations are performed thanks to the computer program "Control Sharing Simulation" presented in Section 5.

Let us regard the Porsche-Volkswagen case with majority quota q = 80%. Figure 1 and Table 1 present the direct ownership relationships in the Porsche and Volkswagen corporate shareholding structure. In this case, we can be interested in which alliances of firms can control companies 4, 5, and 6, for example. After running the program "Control Sharing Simulation" we obtain that no investor alone is able to control these companies. In this case, there are two minimal winning coalitions of investors {1, 2, 3} and {1, 3, 7} that can control these companies, and three winning coalitions: {1, 2, 3}, {1, 3, 7}, and {1, 2, 3, 7}. Porsche Family (1) and Lower Saxony (3) jointly do not manage to control companies 4, 5, and 6. It is necessary cooperation with Qatar (2) or Others (7). In practice, as Others (7) represents the set of small undefined shareholders, an alliance with Qatar (2) seems to be a more reliable coalition.

If we take in consideration only company 6 (Porsche AG) as the target company, and we allow the coalitions of investors and companies, we obtain that there are 63 non-empty coalitions. Five of them are minimal winning coalitions: {5}, {1, 2, 3}, {1, 3, 7}, {2, 3, 4}, {3, 4, 7}, and forty-one are winning. The rest of the coalitions (63 – 41 = 22) are losing. Of course, not knowing the above results, we can ask if a particular coalition is able to exert power over a preset firm or group of firms. For example, let us consider company 6 as a target company, coalition {1, 2, 7} is losing. If we perform the graphical algorithm of the "Control Sharing Simulation" program for the same coalition ({1, 2, 7}), the result is confirmed (see Figure 3). Figure 3 illustrates that jointly, firms 1 and 2 fully control company 4 (Porsche SE), but coalition {1, 2, 7} having 80% of the voting rights in company 5 (Volkswagen AG) is not able to exert power and push for their decision in company 5. Namely, according to some laws, it is necessary to have more than 80% of the voting rights to make important decisions in Volkswagen AG.

Table 1 – The simplified matrix representation of the Porsche Volkswagen case

	Porsche AG (6)	Porsche SE (4)	Volkswagen AG (5)
Lower Saxony (3)			0.200
Others (7)			0.123
Porsche Family (1)		0.900	
Porsche SE (4)			0.507
Qatar (2)		0.100	0.170
Volkswagen AG (5)	1		

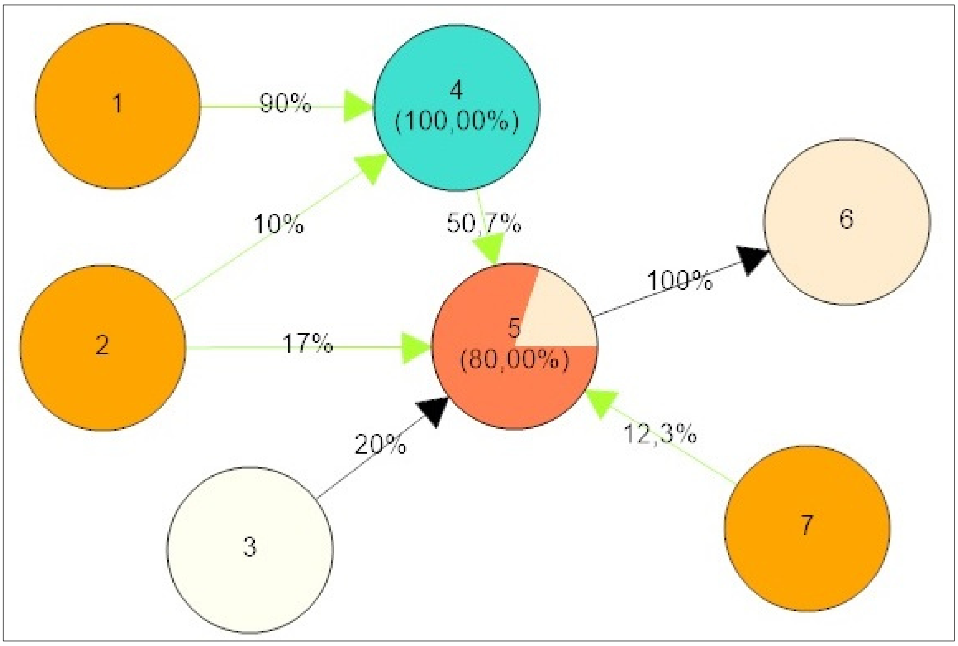


Figure 3 – Porsche-Volkswagen case: levels of control (in percentage) of firms 1, 2, 7 in companies 4, 5, 6.

Of course, the "Control Sharing Simulation" program lets us change the majority quota and perform other simulations. If we change the majority quota to q = 50% in the Porsche-Volkswagen case, we obtain that Porsche Family (1) controls all companies (4, 5, 6); thus, there is only one minimal winning coalition {1} and eight winning coalitions. By the way, all of these winning coalitions contain firm 1 (Porsche Family).

In the Baker and Speiser case (see Figure 2 or Table 2), the corporate shareholding structure has a loop: company 1 (Medallion) is fully controlled by company 4 (HealthChem), then company 3 (HealthMed) has a 41.5% of the voting rights in company 4, and again company 1 (Medallion) possess 10% of the voting rights in company 3. The presence of a loop in a corporate network creates some problems in certain approaches, but not in Denti and Prati. Running the program, we also obtain that no investor in this case is able control all companies (4, 5, 6) itself. In total, there is five losing coalitions: three singular coalitions ({2}, {5}, {6}) and two 2-person coalitions ({2, 6},{5, 6}) – all with firm 6. Next, there are two winning coalitions: {2, 5}, {2, 5, 6}, but only one minimal winning coalition. Namely, player 2 (Speiser) and 5 (Baker) jointly control HealthMed (3), HealthChem (4), and Medallion (1). Thanks to the "graphic algorithm," we can see in Figure 4 the degrees of control (in percentage) of firms 2 (Speiser) and 5 (Baker) in companies 1, 3, and 4. Speiser and Baker fully control Medallion (1) and HealthMed (3); and thanks to indirect control, they have 60% of the voting rights in HealthChem (4). If we take in consideration only company 3, we obtain that there are five minimal winning coalitions that control this company: {1, 2}, {1, 5}, {2, 4}, {2, 5}, {4, 5}, and also five that have control over company 4: {1, 2}, {2, 3}, {2, 5}, {3, 6}, {1, 5, 6}.

Table 2 – The simplified matrix representation of the Speiser and Baker case

	HealthChem (4)	HealthMed (3)	Medallion (1)
Baker (5)	0.085	0.450	
HealthChem (4)			1.000
HealthMed (3)	0.415		
Medallion (1)		0.100	
Others (6)	0.400		
Speiser (2)	0.100	0.450	

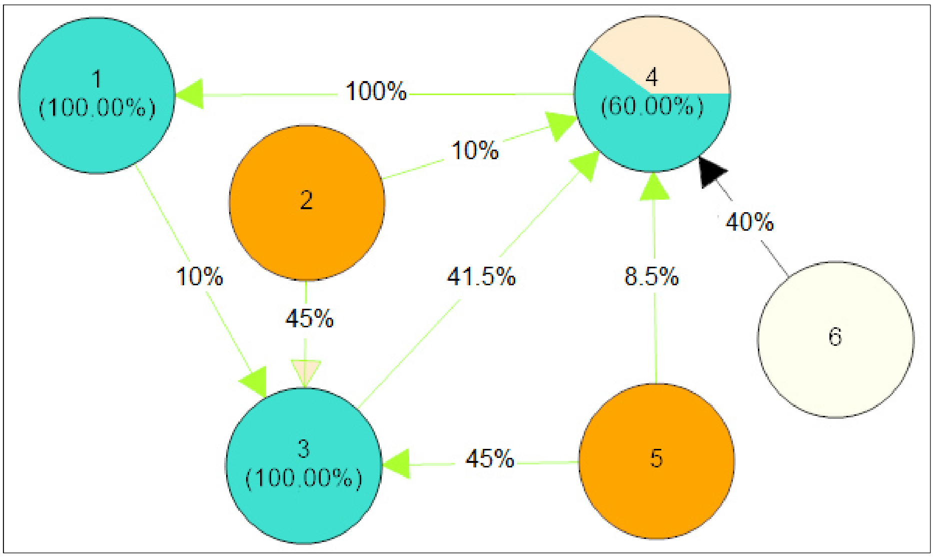


Figure 4 – Baker and Speiser case: levels of control (in percentage) of firms 2 and 5 in companies 1, 3, 4

7. CONCLUDING REMARKS

In this paper, we dealt with the indirect control/power in corporate shareholding networks. This topic is important and complex in financial economics. It is not simple to model and then measure the indirect control in complex corporate networks with a large number of firms and with cross-shareholdings. In the present paper, we presented two real-word examples of shareholding structures, one with the presence of a loop (the Speiser-Baker case) and one without (the Porsche-Volkswagen case).

In the context of game theory, various studies have been made on the modeling and measuring of indirect control in corporate networks. In Section 1, we mentioned some approaches; but in this paper, we only focused on the Denti and Prati model. In Section 6 (using the mentioned Denti and Prati approach), we performed some simulations thanks to the computer program "Control Sharing Simulation" ([12]) for the two examples of corporate shareholding networks mentioned above. The problem of applying the existing approaches to real-word corporate structures is due to the lack of adequate software. The "Control Sharing Simulation" program facilitates the application of the Denti and Prati algorithm. This program allows us to quickly create direct graphs representing a corporate network, read and save graphs to files, run the Denti and Prati algorithm, and finally illustrate graphically the degree of control exerted by a preset coalition of firms on the rest of the companies.

8. REFERENCES

[1] Denti E, Prati N.: *An algorithm for winning coalitions in indirect control of corporations*, Decisions in Economics and Finance, 24(2001), 153–158.

[2] Bajuri N. H., Chakravarty S., Hashim N. H.: *Analysis of corporate control: can the voting power index outshine shareholding size?*, Asian Academy of Management Journal of Accounting and Finance, 10(1)(2014), 75–94.

[3] Shapley L.S., Shubik M.: *A method for evaluating the distributions of power in a committee system*, American Political Science Review, 48(1954), 787–792.

[4] Stach I.: *Shapley-Shubik index*, In: *Encyclopedia of Power, Los Angeles*, K. Dowding (Ed.), SAGE Publications, 2011, 603–606.

[5] Gambarelli G, Owen G., *Indirect control of corporations*, International Journal of Game Theory, 23(1994), 287–30.

[6] Crama Y, Leruth L.: *Control and voting power in corporate networks: concepts and computational aspects*, European Journal of Operational Research, 178(2007), 879–893.

[7] Crama Y, Leruth L.: *Power indices and the measurement of control in corporate structures*, International Game Theory Review, 15(3)(2013), 1–15.

[8] Karos D, Peters H.: *Indirect control and power in mutual control structures*, Games and Economic Behavior, 92(2015), 150–165.

[9] Bertini C., Mercik J., Stach I.: *Indirect control and power*, Operations Research and Decisions, 26(2)(2016), forthcoming.

[10] Mercik J., Łobos K.: *Index of implicit power as a measure of reciprocal ownership*, Springer Lecture Notes in Computer Science 9760, 2016, 132–145.

[11] Denti E, Prati N.: Relevance of winning coalitions in indirect control of corporations, Theory and Decision, 56(2004), 183–192.

[12] Kołodziej, M.: *Indirect control of corporations: analysis of models and their computer implementation*, Master thesis. thesis promoter: Izabella Stach. AGH University of Science and Technology, Faculty of Management, 2011.

A MILP MODEL FOR ROUTE OPTIMIZATION PROBLEM IN A MUNICIPAL MULTI-LANDFILL WASTE COLLECTION SYSTEM

Antoni KORCYL[1], Roger KSIĄŻEK[1], Katarzyna GDOWSKA[1]

[1]AGH University of Science and Technology, Faculty of Management
Mickiewicza 30, 30059 Krakow,
Poland

Abstract:

This paper is devoted to a municipal waste collection system management. The objective is to minimize the total cost of service, while ensuring the desirable level of service quality. A MILP model for route optimization problem in a multi-landfill waste collection system with heterogeneous fleet and time windows was developed. As a result routes are determined and assigned to vehicles of a heterogeneous fleet, and moments of waste collection are determined subject to clients' pre-defined time windows. All the clients are served in their time windows, while the number of vehicles used and the total distance are minimized while the maximal number of clients is served properly.

Keywords:

linear programming, MILP model, VRP, CVRPTW, MDCVRPTW, time windows, transport network

1. INTRODUCTION

This paper is devoted to a municipal waste collection system management. The objective of such a system is to organize and to schedule services, so that the total costs of service is minimized while ensuring the desirable level of service quality. In the presented approach to optimization of waste collection routes the following issues are taken into account: clients must be served accordingly to their predefined time windows, available vehicles of the fleet may go along defined network segments only, the number and capacity of depots and landfills cannot be exceeded, each vehicle can be assigned to at least one depot (the vehicle starts and ends its route in the depot to which the given garbage truck is assigned). After collecting waste from the last client in the route and before going back to the depot each vehicle must be drained at a landfill. While planning the route of a vehicle, we should choose landfill that is located as close as possible to both the last client in the route and the vehicle's home depot, so that the total distance is reduced.

In order to achieve these objectives a mixed-integer linear programming model (MILP model) for route optimization in a municipal multi-landfill waste collection system with multiple vehicles and time windows was developed basing on selected previous works [1,2]. The newly developed model enables the user to find optimal routes in a network containing a specific number of clients (waste collection nodes). The routes are assigned to vehicles of the fleet; at least one route can be assigned to each vehicle, but not all the vehicles must be assigned to any route. The optimal solution guarantees that all the clients are visited and served in their time windows. Moreover, the total number of vehicles used is minimized, so as the total length of routes, while ensuring the maximal number of properly served clients.

The rest of the paper is organized as follows. Section 2 provides a short literature review on the Vehicle Routing Problem (VRP). The newly developed MILP model for route optimization problem in a multi-landfill waste collection system is presented in Section 3. Utilization of the newly developed model is illustrated with a case study described in Section 4. The paper is concluded by the Section 5.

2. VEHICLE ROUTING PROBLEM – LITERATURE REVIEW

Vehicle Routing Problem aims to determine the optimal set of routes to be served by a fleet, so that the total cost of used vehicles is minimized [3–5]. The objective is to determine routes, that is subsets of nodes (waste collection points, clients) to be served one by one in a specific sequence by a specific vehicle of the fleet. Usually the total cost of used vehicles is minimized subject to constraints, which represents specific character of the problem [3,5].

For over fifty years the VRP and route optimization problem in transport networks have been subjects of research conducted in fields of transportation, logistics, and operations research [6,7]. The Vehicle Routing Problem is considered to be the heart of distribution management, since it is a crucial problem faced by companies and organizations engaged in delivery and collecting goods [8]. The Classical VRP is also a popular problem in combinatorial optimization as it generalizes the Travelling Salesman Problem [9]. Studies on this NP-hard problem have resulted in several exact and heuristic techniques of general applicability [8,10–12].

The Classical VRP aims to determine the minimum-cost set of routes subject to constraints that represent the specific character of the given transportation system. This paper refers to a problem which is based on the Capacitated Vehicle Routing Problem (CVRP) and the Vehicle Routing Problem with Time Windows (VRPTW). The CVRP includes parameters and constraints representing vehicle capacity, route segment length, and route segment capacity. The objective of this problem is to determine minimum-cost routes that start and end in the same depot. Client's demand for transportation service is known as well as vehicle capacity; goods shipped/collected by a given vehicle must not exceed the vehicle's capacity. Routes are assigned to the fleet of vehicles; each client can be served by at least one vehicle. In the Vehicle Routing Problem with Time Windows client demand and vehicle capacity is known and cannot be exceed, but it also includes time limits set by customers and transportation company. Moreover, each client must be served in predefined time window, which is defined by the earliest and the latest time when the goods can be delivered to or collected from the client [3,7,8,12].

The Vehicle Routing Problems combining both capacity constraints and time windows were formulated, e.g. the Capacitated Vehicle Routing Problem with Time Windows (CVRPTW). In models for the CVRPTW the objective function expresses the user's needs and constraints represent specific features of the transport network. Such a problem can be formulated as a bi-objective optimization problem, where number of vehicles used for performing the service is maximized and total working time of the fleet is minimized at the same time [13]. The VRPTW can be formulated for a fleet of m vehicle (m-VRPTW). In the m-VRPTW the objective is to determine at least m routes, so that the number of properly served clients is maximized and the total length of routes is minimized [14].

The VRP is modified when transportation network contains more than one depot, so each vehicle must be assigned to one depot where the vehicle's route starts and ends. When capacity and time-windows constraints must be included in the formulation of the problem, we end up with the Multi-Depot Capacitated Vehicle Routing Problem with Time Window (MDCVRPTW). A model for the MDCVRPTW is frequently used as a basis of IT tools for delivery routing.

A solution to the MDCVRPTW is a set of routes to ensure that all the clients are served and the total cost of deliveries is minimal [15–17].

The route optimization problem in a municipal multi-landfill waste collection system to which this paper is devoted can be considered as the VRP with a heterogeneous fleet and time windows. The original aspect of the problem is the network with several nodes representing landfills, where only one landfill can belong to each route. Moreover, a landfill must be the penultimate node in the vehicle's route, since this is where the vehicle can dispose waste before going back to the home depot.

3. MIXED-INTEGER LINEAR PROGRAMING MODEL FOR ROUTE OPTIMIZATION PROBLEM IN A MULTI-LANDFILL WASTE COLLECTION SYSTEM

In this section the newly-developed MILP model for the route optimization problem in a municipal multi-landfill waste collection system is presented. This model is an advanced version of previous ones and can be considered as a multi-depot vehicle routing problem in a heterogeneous fleet and time windows [1,2].

Following assumptions were adopted to the problem:
- for each depot a time window is defined – the earliest and the latest time of leaving the depot,
- for each waste collection node (client) a time window is defined – the earliest and the latest time of serving the client,
- the fleet is heterogeneous,
- there are more than one landfills in the network, a landfill must belong to each route, and only one landfill can belong to each route.

In order to model the route optimization problem in a municipal multi-landfill waste collection system we introduced both binary variables for assigning nodes to routes and routes to vehicles, as well as timing variables for determining arrival times at nodes and waiting times at nodes (for notation used in model see Table 1).

Table 1 – Notation

Sets:		
V	–	set of all the nodes in the system: node 0 represents the depot (the node where every route starts and ends);
N	–	set of system nodes excluding node 0 (the union of sets R and P)
R	–	set of nodes representing waste collection points
P	–	set of nodes representing landfills
K	–	set of vehicles, (contains subsets K_c; subset K_c gathers vehicles of type c);
C	–	set of vehicle types;
Parameters:		
d_i	–	demand for service of waste collection point i (the amount of waste to be collected from client i);
e_i	–	the earliest time of picking up waste from client i (lower limit of i-th client's time window);
l_i	–	the latest time of picking up waste from client i (upper limit of i-th client's time window);
s_i	–	time of service of waste collection point i;
E	–	the earliest time of leaving the depot;
L	–	the latest time of leaving the depot;

q_c	–	capacity of the vehicle of type *c*;
p_c	–	the latest time of returning to the depot of a vehicle of type *c*;
α_c	–	fixed cost of using a vehicle of type *c*;
β_c	–	variable cost of using a vehicle of type *c*;
δ_c	–	waiting cost of a vehicle of type *c*;
n_c	–	number of vehicles of type c;
t_{ij}	–	travel time between waste collection nodes *i* and *j*;
M	–	large positive constant;
γ_1	–	coefficient for the total fixed travel cost;
γ_2	–	coefficient for the total variable travel cost;
γ_3	–	coefficient for the total fixed waiting cost;
Decision variables:		
x_{ijk}	–	binary variable, $x_{ijk} = 1$, if route segment between waste collection nodes *i* and *j* is served by vehicle *k*; otherwise $x_{ijk} = 0$;
y_k	–	binary variable, $y_k = 0$, if vehicle *k* is used; otherwise $y_k = 1$;
a_{ik}	–	timing variable, travel time of vehicle *k* to the waste collection node *i*;
w_{ik}	–	timing variable, waiting time of vehicle *k* in the waste collection node *i*;

Newly developed MIP model for vehicle routing problem in a network with multiple vehicles and time windows is presented below (1)–(24).

Maximize

$$\sum_{k\in K}(1-y_k)+\sum_{i\in N}\sum_{j\in N}\sum_{k\in K}x_{ijk}-\gamma_1\sum_{c\in C}\alpha_c\sum_{k\in K_c}\sum_{j\in N}x_{0jk}-\gamma_2\sum_{c\in C}\beta_c\sum_{k\in K_c}\sum_{i\in N}\sum_{j\in N}t_{ij}x_{ijk}$$
$$-\gamma_3\sum_{c\in C}\delta_c\sum_{k\in K_c}\sum_{j\in N}w_{jk} \tag{1}$$

$$\sum_{j\in V}\sum_{k\in K}x_{ijk}\le 1; i\in N;\ i\ne j \tag{2}$$

$$\sum_{j\in N}x_{0jk}\le 1; k\in K;\ i\ne j \tag{3}$$

$$\sum_{i\in N}x_{i0k}\le 1; k\in K;\ i\ne j \tag{4}$$

$$\sum_{i\in V}x_{ijk}=\sum_{i\in V}x_{jik}; j\in V; k\in K; i\ne j \tag{5}$$

$$x_{ijk}+x_{jik}\le 1; i\in V; j\in V; i\ne j \tag{6}$$

$$x_{iik}=0; k\in K; i\in V \tag{7}$$

$$\sum_{j\in N}x_{0jk}=1-y_k; k\in K \tag{8}$$

$$\sum_{j\in N}x_{j0k}=1-y_k; k\in K \tag{9}$$

$$\sum_{i\in N}\sum_{j\in N}x_{ijk}\le M(1-y_k); k\in K; i\ne j \tag{10}$$

$$\sum_{i \in N} \sum_{j \in V} d_i x_{ijk} \le q_c; k \in K_c; c \in C \tag{11}$$

$$a_{ik} + w_{ik} + s_i + t_{ij} - a_{jk} \le M(1 - x_{ijk}); k \in K; i \in V; j \in N; i \ne j \tag{12}$$

$$a_{jk} - w_{ik} - s_i - t_{ij} - a_{ik} \le M(1 - x_{ijk}); k \in K; i \in V; j \in N; i \ne j \tag{13}$$

$$a_{ik} \le l_i \sum_{j \in V} x_{ijk}; k \in K; i \in N; i \ne j \tag{14}$$

$$e_i \sum_{i \in V} x_{ijk} \le a_{ik} + w_{ik} \le l_i \sum_{j \in V} x_{ijk}; k \in K; i \in N; i \ne j \tag{15}$$

$$E \le a_{0k} \le L; k \in K \tag{16}$$

$$a_{ik} + w_{ik} + s_i \le p_c; k \in K_c; c \in C; i \in N \tag{17}$$

$$\sum_{j \in N} \sum_{k \in K_C} x_{0jk} \le n_c; c \in C \tag{18}$$

$$\sum_{i \in P} \sum_{j \in P} x_{ijk} \le 0; k \in K; i \ne j \tag{19}$$

$$\sum_{i \in R} \sum_{j \in P} x_{ijk} \ge 1(1 - y_k); k \in K; i \ne j \tag{20}$$

$$a_{ik} \ge 0; k \in K; i \in V \tag{21}$$

$$w_{ik} \ge 0; k \in K; i \in V \tag{22}$$

$$x_{ijk} \in \{0,1\}; i \in V; j \in V, i \ne j; k \in K \tag{23}$$

$$y_k \in \{0,1\}; k \in K \tag{24}$$

The objective function (1) guarantees simultaneous optimization of five objectives: minimizing the total number of used vehicles (y_k), maximizing the total number of route segments assigned to vehicle k (x_{ijk}), minimizing the total fixed and variable costs of travel, minimizing the total fixed and variable costs of waiting. Coefficients γ_1, γ_2 and γ_3 were used in the objective function to standardize values of addends.

Constraint (2) ensures that each node can belong to at least one route. In order to ensure that each vehicle dispose collected waste at a landfill, we decompose nodes representing landfills into sets of apparent nodes, so that the same landfill can belong to several routes, because different apparent node is assigned to each route (see Figure 1). After obtaining solution we interpret apparent nodes as the landfill.

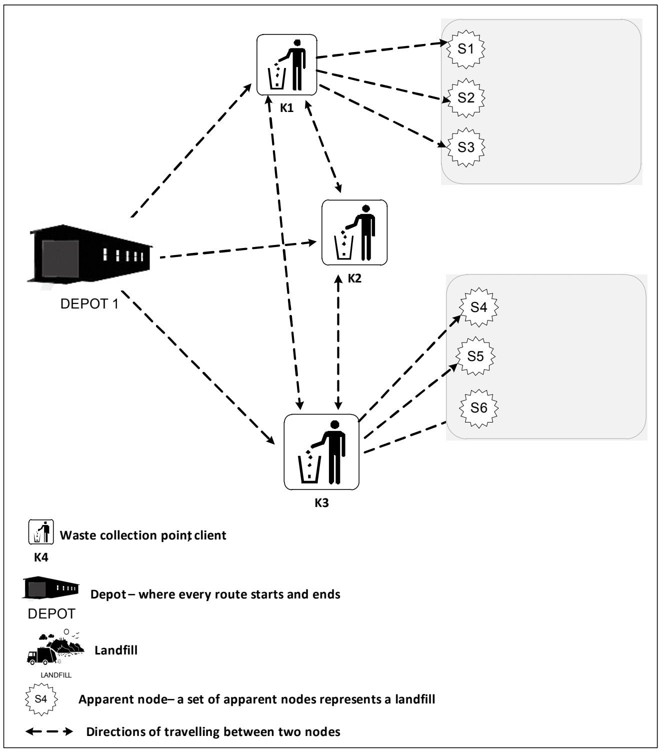


Figure 1 – The way of interpreting nodes as waste collection points (clients) and landfills

Constraints (3)–(5) guarantees that, if used, each vehicle starts and ends its route at its home depot and just before going back to the home depot each vehicle visit a landfill to dispose waste. If a vehicle leaves its home depot, it has to return – constraints (8) and (9). Along the route segment between neighboring waste collection nodes i and j goes only the vehicle that serves both clients i and j (6). Constraint (7) eliminates subroutines. Constraint (10) makes it possible to assign a vehicle to a route segment only if it is used. The total amount of waste collected along the route assigned to vehicle k of type c does not exceed the capacity of the vehicle. Vehicle travel balance equations (12) and (13) determine arrival times to waste collection points in the network. Constraints (14)–(17) refer to upper and lower limits of time windows set for nodes. Time windows of landfill nodes should ensure that vehicle can go there after collecting waste from client nodes – constraints (14) and (15). The working day represented with the time window of the depot should be wide enough, so that the clients can be served according to their time windows – constraints (16) and (17). Constraint (18) defines the number of available vehicles of type c. Constraint (19) refers to the landfill node decomposed to a set of apparent nodes and it forbids going from one apparent node to another. Each route has to include the visit at a landfill, so one apparent node has to be assigned to each route (20). Constraints (21)–(24) ensures variable nonnegativity and integrality.

4. A CASE STUDY EXAMPLE

To demonstrate the usage of the newly developed MILP model for route optimization problem in a multi-landfill waste collection system, a single-depot multi-landfill waste collection system with heterogeneous fleet was designed. The network consists of 8 nodes: N_1 – the depot, where every vehicle starts and ends its route; S_1 and S_2 – landfills, each of them is represented by four apparent nodes; K_1, …, K_5 – waste collection points (clients). As it has been already mentioned each route has to include the visit at a landfill to dispose collected waste, so one apparent node has to be assigned to each route.

The fleet consists of vehicles of two different types C_1 and C_2 – vehicles P_1 and P_2 are of type C_1 and have capacity q_{C1} and vehicles P_3 and P_4 are of type C_2 and have capacity q_{C2}. Waste amount to be collected from each client is known (d_{K1}, …, d_{K5}). We assumed that in the planning horizon each client is visited and served only once. The aim of vehicle routing problem formulated for the above mentioned waste collection system is to obtain one-day schedule of picking-up waste from clients.

Service time of each client is known (s_{K1},…, s_{K6}) as well as the part of the day, when the client should be served – client k should be visited not earlier than moment e_k and not later than moment l_k. Vehicles can leave the depot N1 not earlier than in moment E and not later than in moment L. We assumed that coefficients γ_1, γ_2, and γ_3 are equal 0.0001. A scheme of a single-depot multi-landfills capacitated waste collection problem is presented in Figure 2. and the data are gathered in Tables 2–5.

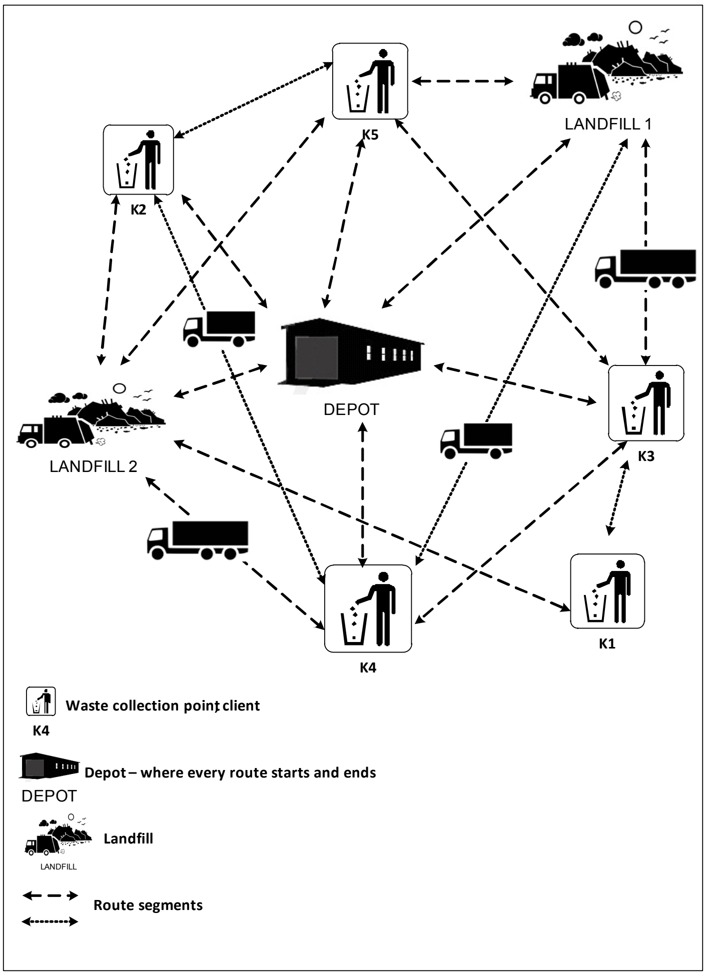


Figure 2 – A scheme of a single-depot multi-landfills capacitated waste collection problem

Table 2 – Data: values of parameters referring to nodes

Node	Waste amount d_k	Time of service s_k	The earliest moment of service e_k	The latest moment of service l_k
K_1	10	1	0	50
K_2	30	1	0	50
K_3	10	1	50	100
K_4	30	1	50	100
K_5	10	1	50	100
S_1	0	0	100	200
S_2	0	0	100	200
N_1	–	–	$E = 0$	$L = 50$

Table 3 – Data: values of parameters referring to vehicles

Vehicle C_1:						
p	q_p	p_p	α_p	β_p	δ_p	n_p
P_1	20	200	100	8	1	2
P_2	20	200	100	8	1	2
Vehicle C_2:						
p	q_p	p_p	α_p	β_p	δ_p	n_p
P_3	70	200	500	10	1	2
P_4	70	200	500	10	1	2

Table 4 – Distances between nodes

	N_1	K_1	K_2	K_3	K_4	K_5	S_1	S_2
N_1	0	7	7	6	5	7	13	19
K_1	7	0	14	6	10	4	17	19
K_2	7	14	0	12	7	13	13	20
K_3	6	6	12	0	11	8	11	23
K_4	5	10	7	11	0	7	17	14
K_5	7	4	13	8	7	0	18	15
S_1	13	17	13	11	17	18	0	32
S_2	19	19	20	23	14	15	32	0

The optimal solution were found for the presented example. The solution is presented in the Table 5. All the clients are served, all the vehicles were used for performing services, and waste is disposed at both landfills. We can observe that the model guarantees that each route includes at least two nodes and a depot. Since it is mandatory that a landfill is the penultimate node of a route, a route depot–client–landfill–depot is possible. In contrary to the model presented in [2], here it is possible that a vehicle serves one client only.

Table 5 – Obtained solution: routes assigned to vehicles

Routes:							
Vehicle P_1							
i	→	j	$a_i(P_1)$	s_i	$w_i(P_1)$	t_{ij}	d_j
0	→	5	50	0	24	7	0
5	→	9	81	1	0	18	10
9	→	0	100	0	0	13	0
Vehicle P_2							
i	→	j	$a_i(P_2)$	s_i	$w_i(P_2)$	t_{ij}	d_j
0	→	3	50	0	0	6	0
3	→	13	56	1	0	23	10
13	→	0	80	0	20	19	0
Vehicle P3							
i	→	j	$a_i(P_3)$	s_i	$w_i(P_3)$	t_{ij}	d_j
0	→	1	28	0	0	7	0
1	→	2	35	1	0	14	10
2	→	12	50	1	0	20	30
12	→	0	71	0	29	19	0
Vehicle P4							
i	→	j	$a_i(P_4)$	s_i	$w_i(P_4)$	t_{ij}	d_j
0	→	4	50	0	0	5	0
4	→	8	55	1	0	17	30
8	→	0	73	0	27	13	0

5. CONCLUDING REMARKS

The route optimization problem in a municipal multi-landfill waste collection system together with the newly developed MILP model is a stage of research on decision-making in municipal waste collection system management. Presented case study and other computational experiments shows that the model may be utilized for determining routes for garbage trucks, so that the total number of used vehicles is minimized as well as the total length of routes. The total length of routes is decreased by choosing this landfill, which is closer both to the last client in the route and the depot. For small waste collection system the optimal solution is obtained in several seconds.

Further research should be focused on multi-depot systems and capacitated vehicles and route segments. Computational experiments should be conducted for longer time horizon and for bigger networks.

6. REFERENCES

[1] Jiang J., Ng K.M., Poh K.L., Teo K.M.: *Vehicle routing problem with a heterogeneous fleet and time windows*, Expert Systems with Applications, 41(2015), 3748–3760.

[2] Korcyl A., Gdowska K., Książek R.: *Optymalizacja tras odbioru odpadów komunalnych z wykorzystaniem różnych typów pojazdów i ograniczeniami czasowymi w obsłudze klienta*, Logistyka, 4(2015), 9202–9211.

[3] Ambroziak T., Jachimowski R.: *Wybrane aspekty zagadnienia okien czasowych w problemie trasowania pojazdów*, Automatyka, 15/2(2011), 51–59.

[4] Hanczar P.: *Wspomaganie decyzji w obszarze wyznaczania tras pojazdów*, Decyzje, 13(2010), 55–83.

[5] Fischer M.: *Vehicle routing*. In *Handbooks in OR & MS Vol. 8*, M.O. Ball, T.L. Magnanti, C.L. Monma, G.L. Nemhauser (eds.), Elsevier Science Publisher 1995, 1–33.

[6] Dantzig G.B., Ramser J.H.: *The truck dispatching problem*, Management Science, 6/1959, 80–91.

[7] Toth P., Vigo D.: *The Vehicle Routing Problem*, Monographs on Discrete Mathematics and Applications, SIAM 2002

[8] Cordeau J.-F., Laporte G., Savelsbergh M.W.P., Vigo D.: *Vehicle Routing*. In *Handbook in OR & MS, Vol. 14*, C. Barnhart and G. Laporte (eds.), Elsevier B.V. 2007, 367–428.

[9] Laporte G.: *The travelling salesman problem: an overview of exact and approximate algorithms*, European Journal of Operational Research, 59(1992), 231–247.

[10] El-Sherbeny N.A.: *Vehicle routing with time windows: An overview of exact, heuristic and metaheuristic methods*, Journal of King Saud University (Science), 22(2010), 123–131.

[11] Yeun L.C., Ismail W.R., Omar K., Zirour M.: *Vehicle Routing Problem: Models and Solutions*, Journal of Quality Measurement and Analysis, 4/1(2008), 205–218.

[12] Crainic G., Laporte G.: *Fleet Management and Logistics*, Kluwer Academic Publisher 2000.

[12] Cordeau J.-F., Laporte G, Mecier A.: *A unified tabu search heuristic for vehicle routing problems with time windows*, Journal of Operational Research Society, 52(2001), 928–936.

[13] Sousa J.C., Biswasa H.A., Britob R., Silveira A.: *A Multi Objective Approach to solve Capacitated Vehicle Routing Problems with Time Windows Using Mixed Integer Linear Programming*, International Journal of Advanced Science and Technology, 28(2011), 1–8.

[14] Lau H.C., Sim M., Teo K.M.: *Vehicle routing problem with time windows and a limited number of vehicles*, European Journal of Operational Research, 148(2003), 559–569.

[15] Shankar H., Mani G., Pandey K.: *GIS Based Solution of Multi-Depot Capacitated Vehicle Routing Problem with Time Window Using Tabu Search Algorithm*, International Journal of Traffic and Transportation Engineering, 3/2(2014), 83–100.

[16] Wei B., Shi H.: *Research on Multiple Depots Open-path VRPTW Based on the Whole Vehicle Delivery and Its Implementation*, Information and Control, 34/3(2005), 350–355.

[17] Hoff A., Andersson H., Christiansen M., Hasle G., Løkettangen A.: *Industrial aspects and literature survey: Fleet composition and routing*, Computers & Operations Research, 37/12(2010), 2041–2061.

THE ROLE OF BUFFER WAREHOUSES IN SELECTED PRODUTION SYSTEMS

Jolanta KRYSTEK[1], Sara ALSZER[1]

[1]Silesian University of Technology,
Faculty Of Automatic Control,Electronics and Computer Science
Akademicka 16, Gliwice,
Poland

Abstract:

In this article the most important aspects related to the specifics of production in the Flexible Manufacturing System (FMS) and importance and capabilities of a sample designed model of FMS system are presented. There is also described an example of the multiversion production process – production of cars. Three major area of automobile production plants are shown, namely: body shop, paint shop and the assembly shop. This paper presents the Car Sequencing Problem (CSP), widely discussed in the literature, with reference to the three above-mentioned stages. There is pointed out the simplicity of the Car Sequencing Problem known from the literature in relation to the sequencing of vehicles on the real production lines. In addition, various types of buffer warehouses are defined and importance of loop buffer in the production of cars is discussed.

Keywords:

Flexible Manufacturing System, Car Sequencing Problem, stocks and buffers, multiversion production

1. INTRODUCTION

Flexible Manufacturing Systems (FMS) are the most expensive industrial facilities, hence it is important to make optimal use of all the opportunities offered by their productive capability. Due to a limited access to such systems for researchers and students, there was designed and built the laboratory stand: it is a modular, educational, flexible manufacturing system (MODES). The MODES system (Figure 1) allows to track and analyze multiversion production. The continuity of the analyzed process and proper sequence of orders are secured through the use of storage carousel. The final product is the one of 52 sets of discs with optional equipment, which is available in two versions: small or large ball. Discs used in this project are reusable, made of aluminum or plastic and are in two different colours: black or white.

The MODES system elements are physical models of components of real production systems found in the industry. This stand was equipped with components that allow to simulate processes and real events of production facilities. It allows to simulate the various elements of production processes such as: multiversion assembly, components delivery planning, distribution requirements planning (DRP), material requirements planning (MRP), planning of throughput of individual subsystems, identification of bottlenecks, changeovers, quality control, palletizing, analysis of conform subsystems capability and mainly production planning (rhythmic, repetitive, mass production) and tasks sequencing.

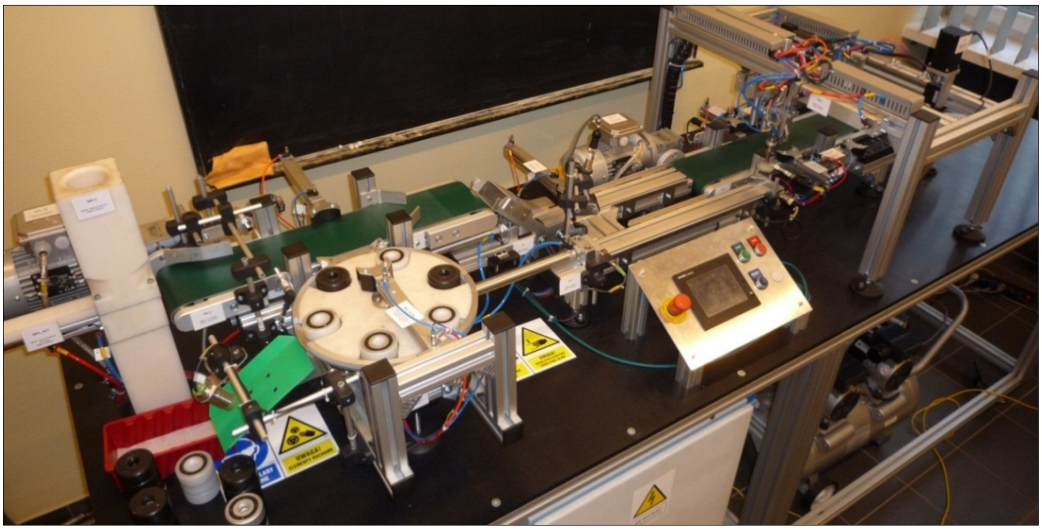


Figure 1 – The laboratory stand

The designed and built laboratory stand serves among other things to analyze the functioning of buffer warehouse in the actual production systems, mainly in the production of cars. It is an introduction for looking the solution of the more complex Car Sequencing Problem, that occurs on the real production line. The simplified process of cars production is discussed in the following sections.

2. DESCRIPTION OF CAR SEQUENCING PROBLEM

Production of cars consists of several steps that are following each other according to a specific order – sequentially. Although the models of the vehicles, that are currently produced on the line, are similar to each other, it is possible to distinguish some features, that are characteristic for the particular types of a given car model. Customer buying a vehicle can determine not only the colour of the car, but also many elements of equipment, for example: sunroof, air conditioning, embedding navigation and others. This indicates that production of cars can be classified as a multiversion production. This implies the requirement to plan an appropriate sequence of cars on the production line to optimize production, both in terms of costs and time needed for machines and robots retooling or in term of productivity [1]. This problem has been defined in the literature as a Car Sequencing Problem (CSP). It has been shown [2,3] that this problem belongs to the NP-hard problems, so there are not any known algorithms that solves the problem in a polynomial time [4,5].

Car Sequencing Problem was first introduced in 1986 by Parello [6] and a formulation of this problem was slightly different from the modern understanding the CSP problem. The issue described by Parello concerned scheduling a set of vehicles on the assembly line to meet imposed assumptions about the throughtput of this line. In 2005 the French Society of Operations Research and Decision Analysis organized a *ROADEF Challenge 2005* with the Car Sequencing Problem as a subject. The organizers required to take into account not only capacity constraints imposed by assembly line, but also paint batching constraints (paint shop) and two categories of capacity constraints – high and low priority constraints. Thereby to solve the CSP problem proposed by Renault it had to include all three plant shops (Figure 2): body shop, paint shop and assembly shop [7]. The Car Sequencing Problem presented in this article is a reduced formulation of problem in relation to the real world problem, which takes into account occurrence of buffers in the production line of cars.

In the initial phase of cars production, in the body shop, robots and operators are welding the various parts of the vehicles to form right structure of the car. Then the connected parts are sent to a paint shop, where they are painted by robots equipped with spray guns. Therefore, at their way out from body shop cars should be arranged in a specific order, depending on colour which they will be painted on. In the last phase, assembly shop, various components are added to the vehicles, adequately to the selected options [7]. A different number of additional components may characterize each configuration.

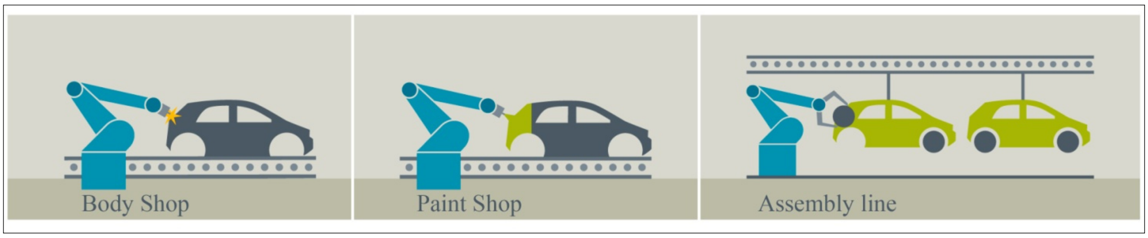


Figure 2 – Stages of the production line
(source: own development on the basis of www.industry.siemens.com)

In the following sections there are presented characteristics of two plant shops of car production line: paint shop and assembly shop, from a perspective of the constraints which affects sequencing vehicles along each part of a line.

2.1. Paint shop

There are two types of paint shop. The first type is the paint shop equipped with several robot stations, which cannot retool. Therefore each station is responsible for painting a vehicle in different colour. Thus, the only constraint for this type of branch is the need for periodic cleaning of the robot's nozzles in order to ensure a sufficiently high quality painting services. If the spray guns are cleaned often enough, it comes to agglutination. The cleaning takes place periodically, so the time interval should be predefined. In this case, the throughtput of the line does not affect the sequence of vehicles transported to paint shop [1,7,8].

The second type is the paint shop equipped with a robot stations, which are retooled every time the colour changes. The capacity of production line for the second type of paint shop depends not only on the length of the cleaning guns for each change of colour, but also on a periodic cleaning of paint guns, which is similar to the first type of paint shop. Two examples of colour sequences for the second type of paint shop, presented in Figure 3., shows the effect of cars alignment with the frequency of the cleaning guns. It is assumed that along the line there is located only one robot and its gun is cleaned periodically every three cars. As can be seen, in both cases, the nozzle should be cleaned at the beginning of the next production day, because of the planned change of colour. In addition, in the first case (Figure 3 – SEQUENCE A) it is necessary to clean the gun twice – the first time due to the periodic cleaning, the second time due to change of colour. However, in the second case there is only one cleaning included both periodic cleaning and cleaning due to a colour change. It illustrates the importance of proper planning car sequences along the line. The right sequence of cars plays important role in production optimization, especially for the second type of paint shop [1,7,8].

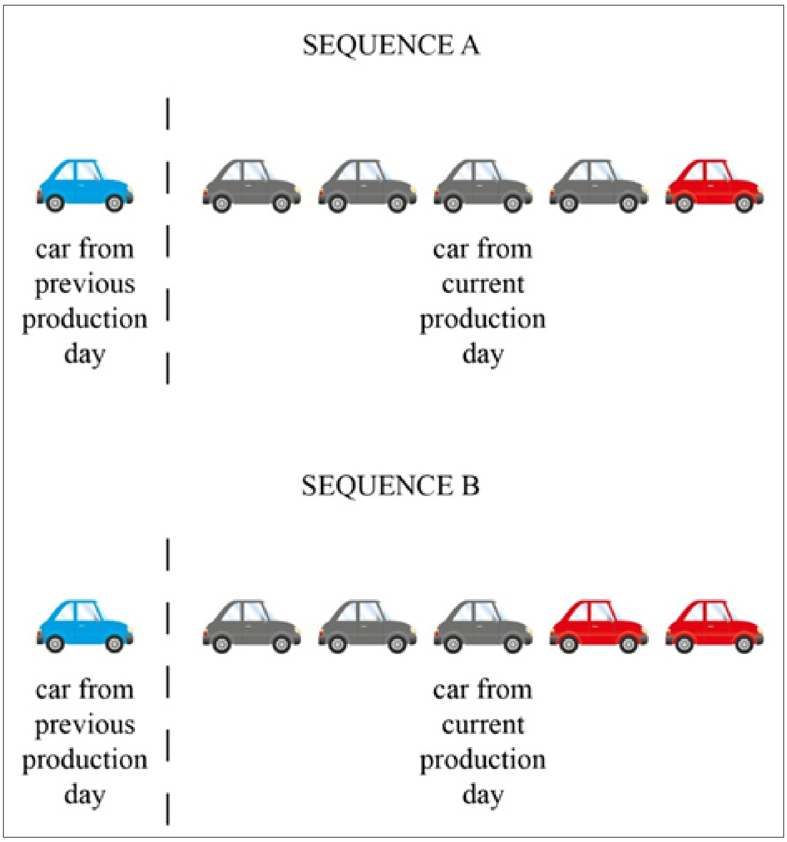


Figure 3 – Sample colour changes for the second type of paint
(source: own development on the basis of [1])

Both cleaning of spray guns and retooling causes delays. If they increase, more robots have to be used. As a result of periodic cleaning or colour change increases not only the consumption of a solvent, but also the consumption of a paint. During flushing of spray guns, some paint, which remains in the nozzle and on the walls, will not be used, because of its removal during the cleaning process. It proves, that the consumption of paint increases. A similar situation takes place when the periodic washing of nozzle will not be taken to account during the sequencing of cars, as shown in Figure 3 (SEQUENCE A).

Therefore the aim of a paint shop is to minimize a number of colour changes (the number of necessary cleanings), allowing to reduce both costs and production time [1,7,8].

2.2. The body shop and the assembly shop

In the body shop and the assembly shop there is a problem of an appropriate arrangement of car sequence. It is related to a produced type of a car model – the vehicle can be three- or five-door and the decision about it is made in the body shop. The car can be also equipped with additional components which are installed in the assembly shop [1].

Therefore the aim of the body shop and the assembly shop is to smooth a workload along a line, by balancing an effort in a different working stations [7]. The method of balancing the assembly line consists even a distribution of operations between workstations, so the idle time is minimal [9]. From the perspective of the Car Sequencing Problem balancing of the assembly line means an even distribution of a workload along a car production line, which requires extra assembling operations (installing additional components). It allows to avoid overload of the station in assembly shop [7].

2.3. Definition of the Car Sequencing Problem

Based on [7,8] a Car Sequencing Problem could be defined by a tuple ($V, NCp, N_{cp}/Q_{cp}, NCl, NVR, NConf, \delta_k$), such as:

$V = \{v_{1,cl,k}, \ldots, v_{NPos,cl,k}\}$ is a set of cars to schedule in a given time. Each of the variables $v_{i,cl,k}$ defines both the configuration and a colour of the *i*-th vehicle;

NCp is a number of possible components;

N_{cp}/Q_{cp} is a ratio constraint for the component *cp*, where $cp \in \{1, \ldots, NCp\}$;

NCl is a number of possible colours;

NVR is a paint batch limit, this parameter defines a maximum number of vehicles which could be painted in a row in the same colour;

δ_k is a demand for the configuration *k*;

NConf is a number of configurations.

2.4. Solution of the Car Sequencing Problem

Solving the Car Sequencing Problem is finding a sequence *V*, thereby defining the order in which the vehicles are passed through the assembly line. The decision problem determinates the possibility of finding a sequence (*V*) of vehicles that meets all the imposed constraints. The point of the optimization problem is to find the schedule, for which the value of the cost function is the smallest [10].

The ROADEF organizers defined three different priority levels of constraints to be considered: paint shop constraints, important assembly line constraints and less important assembly line constraints, so the hierarchical objective function was built. It means that the function consists of three objectives to optimize: the number of color changes (CC), the number of HPRC (*High Priority Ratio Constraints*) violations and the number of LPRC (*Low Priority Ratio Constraints*) violations. To each type of constraint is assigned another weight, so the objective function is a weighted sum of all these constraints (1) [1,7]:

$$Z = 10^6 \times N * CC + 10^3 \times N * HPRC + 1 \times N * LPRC \quad (1)$$

In his work [7] Ricardo noticed that it is not clear, how the organizers calculated the weights and the objective functions are not normalized.

It should be noted that two different cars from the set *V* may require an installation of the same components. Then these vehicles are classified into the one group. ie. if there are *k* different classes of cars, then the set *V* is a sum of all these subsets: V_k: $V = V_1 \cup V_2 \cup \ldots V_k$ [8].

As has been mentioned earlier, the presented problem of car sequencing omits the existence of buffer warehouse between stages and inside individual shops and lines. However, this buffer occurs in the actual production lines, so with respect to that, it is suggested to redefine the mathematical model of the CSP problem. Research of solving this problem should take into the account the occurrence of buffer warehouses, because they play an important role in the planning of production and in the sequencing of production orders.

3. THE ROLE OF BUFFER WAREHOUSES IN PRODUTION SYSTEM

The buffer warehouses are the elements of production processes, often used to ensure continuity of production. They could occur in the form of physical devices, intended to be used in the system "product for man". Their main purpose is to storage components, spare parts, tools and many others. These devices are widely used, for example in: warehouses, production lines, distribution centers, wholesaler's and can also be used for archiving documents in the office. In production systems very often we have to deal with a production planning with limited production resources. All this constraints (bottlenecks) have to be taken into account when creating the production schedule. During production planning it is worth to take into account Theory of Constraints [11], which provides knowledge to enable rational use of available resources. This knowledge allows to detect limitations of a production system and to manage them effectively in order to increase the efficiency of such system. The Theory of Constraints is a foundation of Drum–Buffer–Rope (algorithm DBR). One element of this algorithm is a buffer, which task is to ensure a stable flow. The buffer is placed before the bottleneck (constraint buffer) and assembly station (assembly buffer) [12]. There are two types of buffers:

- temporary (material for bottleneck and assembly station is supplied in advance),
- quantitative (before the critical resource and assembly station is given a specific amount of material to be processed in this workplace.

4. TYPES OF BUFFER WAREHOUSES IN THE REAL PRODUCTION SYSTEM

Application of buffer warehouses along the production line allows to change the sequence of products (for example cars) in front and behind of various stages of the production system, and inside the branches. This is an important point in optimization of a production process. There are three main types of buffers used in the production of cars [1]:

- parallel buffers,
- random access buffers,
- loop buffers.

When a structure with parallel buffers (Figure 4) is used, the decision of locating the vehicle on a buffer line is taken at the end of the ingoing line. In turn, the outgoing line is successively filled with cars taken from the parallel buffer line, according to defined priority, eg. FIFO strategy (*First In – First Out*).

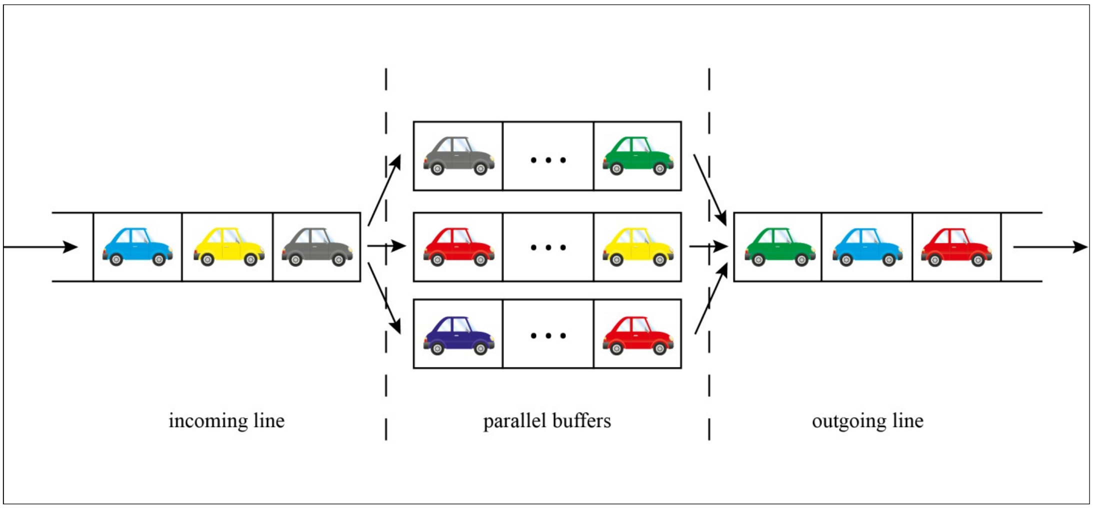


Figure 4 – Production line with parallel buffers strategy
(source: own development on the basis of [8])

The random access buffer (Figure 5) ensures free access to stored parts – it means that this type of the production line structure allows to redirect into outgoing line any vehicles from the buffer.

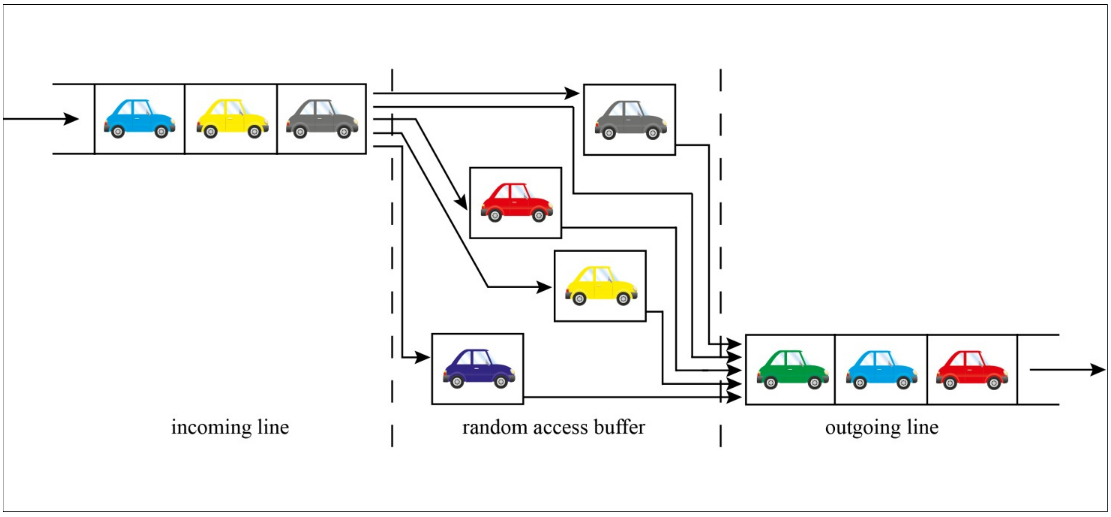


Figure 5 – Production line with random access buffer strategy
(source: own development on the basis of [8])

Carousel storage (Figure 6) acts as a buffer warehouse, to which the products or parts of items, that are not currently needed in production process, are directed. Only at the moment when there is a demand for the product placed in the buffer, this product will be restored from the warehouse to the production line. In order to restore the product, the carousel buffer must rotate, so that the restoring element achieves so called drop position (right position of outgoing production line). It is the only position from which part can be restored back to the production line. If the product is directed to the warehouse, the buffer must rotate, so that the so called access position (the nearest unoccupied position) will be at the height of the incoming production line. During the movement, in order to achieve access or drop position, all buffer's positions are moving simultaneously. The direction of movement depends on the length of the distance, which the restored product must cover or on that, where is the nearest unoccupied position.

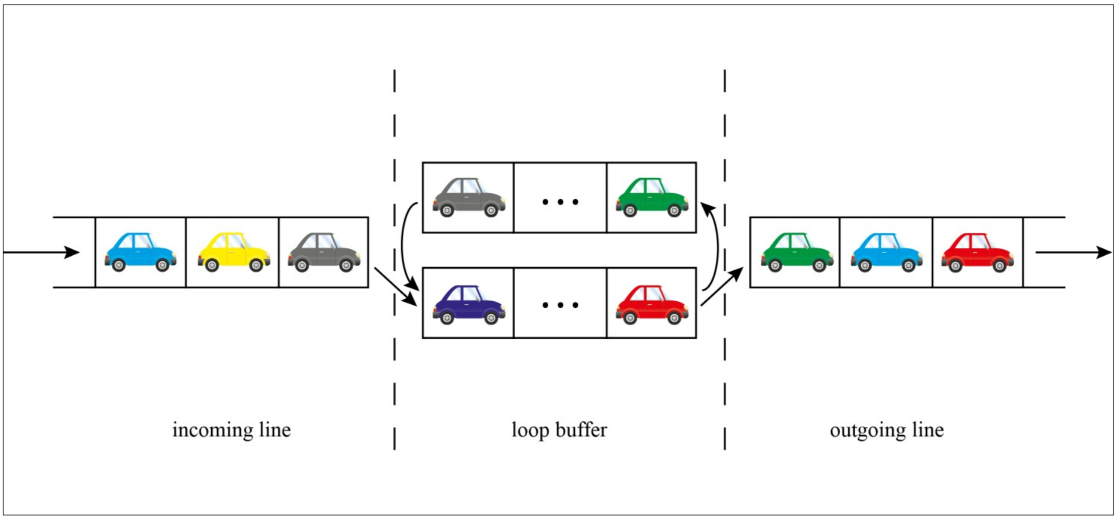


Figure 6 – Production line with loop buffer strategy
(source: own development on the basis of [8])

Loop buffers are mostly used after the body shop, where it is checked if the element of car's equipment has been installed correctly. If the quality control reveals irregularities in the installation, the vehicle is placed in the buffer. In turn is taken from the buffer warehouse, repaired and again placed in the buffer, from which can be restored to the production line.

5. SUMMARY

Due to the fact, that the flexible manufacturing systems belong to the most expensive industrial facilities, the laboratory stands are designed and built. They are physical models of components of real production systems found in the industry. The production process implemented in the modular, educational, flexible manufacturing system (MODES) and located in the Laboratory of Flexible Manufacturing Systems at the Silesian University, at Faculty of Automatic Control, Electronics and Computer Science, served as an example of multiversion production. The simulation of the production process, executed on the laboratory stand, was used in the analysis of the problem of production orders sequencing. The MODES system allows to highlight, how important are the buffer storages, according to the problem of car sequencing in a real production system.

6. ACKNOWLEDGEMENTS

This work was supported by Polish Ministry of Science and Higher Education under internal grants BK-213/RAu1/2016 for Institute of Automatic Control, Silesian University of Technology, Gliwice, Poland.

7. REFERENCES

[1] Prandtstetter, M.: *Exact and heuristic methods for solving the car sequencing problem*, MSc thesis, Vienna University of Technology, Institute of Computer Graphics and Algorithms, Vienna 2005, www.ac.tuwien.ac.at, 28-03-2016.

[2] Gent, I.P.: Two *results on car–sequencing problems*. Technical report, www.citeseerx.ist.psu.edu, 29-03-2016.

[3] Kis,T.: *On the complexity of the car sequencing problem*, Operations Research Letters, 32(2004), 331–335.

[4] Herka, W., Sewastianow P.: *Szeregowanie zadań na jednej maszynie (aspekt wąskiego gardła) w warunkach niepewności rozmyto-interwałowej*, www.zsiie.icis.pcz.pl, 30-03-2016.

[5] Sobaszek, Ł., Gola A.: *Zastosowanie Matlaba w szeregowaniu zadań produkcyjnych*. In: *Technologie informacyjne w technice i kształceniu*, M.M. Janczarek, J. Lipski (Eds.), Monografie – Politechnika Lubelska, Politechnika Lubelska, Lublin 2013, 101–114.

[6] Parello, B.D. et al.: *Job-shop scheduling using automated reasoning: a case study of the car sequencing problem*, Journal of Automated Reasoning, 2(1986), 1–42.

[7] Ricardo, J.: *Solving the Car Sequencing Problem from a Multiobjective Perspective*, MSc thesis., Universidade Técnica de Lisboa, Lisbonne 2007, www.fenix.tecnico.ulisboa.pt, 25-03-2016.

[8] Solnon, C. et al.: *The Car Sequencing Problem: Overview of State-of-the-Art Methods and Industrial Case-Study of the Roadef 2005 Challenge Problem*, European Journal of Operational Research 191(3)(2008), 912–927.

[9] Grzechca, W.: *Linia montażowa z wieloma operatorami na pojedynczej stacji roboczej*, Proceedings of Conference Innowacje w Zarządzaniu i Inżynierii Produkcji, Zakopane, February 2014, vol. 1, 540–551.

[10] Perron, L., Shaw P.: *Combining forces to solve the car sequencing problem,* Proceedings of CP-AI-OR'2004, vol. 3011 of LNCS, Springer, 2004, 225–239.

[11] Goldratt, E.: *Cel: doskonałość w produkcji*, Werbel, Warszawa, 2000.

[12] Schragenheim, H., Dettmer W.: *Simplified Drum-Buffer-Rope. A Whole System Approach to High Velocity Manufacturing*, 2000, www.insyte-consulting.com, 25-03-2016.

ANALYSIS OF THE MOST POPULAR INTERURBAN TRANSPORT MODES AMONG CRACOW STUDENTS OF STATE UNIVERSITIES

Małgorzata KUŹNAR[1], Elżbieta WYRAZ[2]

[1]Cracow University of Technology,
Reliability and Technical Exploitation Division, Cracow,
Poland
[2]Cracow University of Technology, Logistics Systems Division, Cracow,
Poland

Abstract:

Travelers communication behavior are influenced by many factors, such as motivation, direction of movement and distance of travel. This paper presents survey results conducted on Cracow students of State Universities. Among the various groups of fields (economic and administration, social, technical and engineering, humanist, pedagogical, medical, and others), students were randomly selected. Subsequently they answered a number of questions connected with the most elected intercity transportation. The research group consisted of 3008 people and corresponded in a quantitative way the percentage structure of the different fields groups of Cracow students. The test results have been included both socio-demographic, as well as qualitative factors. The results provide a basis for shaping the appropriate strategies of interurban transportation development.

Keywords:

interurban transportation modes, transport development strategy, transport services accessibility, quality of interurban transport, intercity communication

1. INTRODUCTION

Nowadays an increasing share of cars during traveling both in the city and beyond can be noticed. Due to the type of roads on which cars move, roads can be divided into national roads (including motorways and expressways, international roads, roads constituting links to ensure the national road network, roads of defense implications), regional roads (roads that combine the towns, which have relevance for the region and they are not included in the national roads), county roads (roads owned by the relevant local government districts) and municipal roads (roads of local importance not classified into other categories, which supplement the roads servicing local needs, excluding internal roads).

In Malopolska region in 2010, the growth factor of traffic on the network of regional roads in comparison with this factor in 2005 was 1.26 [1]. Recorded then the highest traffic loads amount to an average of 5500 vehicles / day concerned the region of Malopolska. Similarly, as in the case of a network of provincial roads in the area of Malopolska, growth rate of traffic on the national roads has also increased compared to 2005. The average number of vehicles per day was 12,953 and represented the second largest value indicating the traffic load of national roads (including international roads) in Poland [2].

The predominant percentage of travel is made by cars. Participation in the car traffic on national roads is about 70%, and on provincial roads about 80% of all motor vehicles [2]. Significant differences can be seen in relation to the percentage share of buses, which account for about 1% of vehicles on the national and provincial roads. Less congested traffic in both urban and its circumcision can be achieved by changing the modal split in the movement towards environmentally friendly transport. In the city, change the mean of transport from a car to a bus or a tram, and during interurban travel moving by train or bus, reduces the number of vehicles on the road. Depending on the assumed rate of filling the car can be concluded that one bus replaces from 30 (using only seats) up to 70 passenger cars.

2. SOCIO-DEMOGRAPHIC AND QUALITATIVE FACTORS

The choice of means of transportation is dependent on a number of socio-demographic and qualitative factors. Communication behavior among travelers are influenced by the motivation, direction of movement and distance. Factors such as gender, age, car ownership, employment status and number of children belonging to the socio-demographic factors influence the motivation of traveling people [3]. The research of mutual influence of these factors on motivation and choice of means of transport, have been presented among others in the papers [3–7]. The choice of means of transport is also dependent on the qualitative factors. The assessment of these factors is subjective evaluation made by each traveler. These factors can be divided into time criteria, spatial criteria, criteria related to weather conditions and the availability of transportation means. The criteria of time can include such factors as the total travel time, time to come to the means of transport, the waiting time for a means of transport and the time to reach from the means of transport to the destination. Distance between start and target, as well as the distance that need to be overcome to get to mode of transport—usually to the stop (bus, rail), and then from the stop to the destination, they belong to the spatial criteria. Important for traveling is also the number of transfers, time of a day, and whether parking space is close to the destination—these are the factors which belong to the criterion of the accessibility. Factors such as the ability to decide by a traveler about the route of travel, the possibility of door to door transportation, the availability of a place to seat during the journey, the safety of the vehicle and the habits of a traveler to the mean of transport are also a very important factors which have an impact on a final decision [7,8]. The dilemma of the mode of transport choice requires knowledge of factors generally referred to as the communication behaviors of people traveling. Proper diagnosis of the causes of choice may allow the formation of these behaviors in terms of alternatives to car transport.

3. AVAILABILITY OF TRANSPORT SERVICES IN THE REGION

The authorities of the Malopolska Region correctly point out that in the Malopolska province transport sector in recent decades has been underfunded and underinvested. As a result, it does not conform to the needs resulting from the economic development of the country, as well as the Polish membership in the European Union. This applies to both goods and passenger transport. Transportation and Communication Department of the Marshal's Office has issued the document specifying the strategies for the development of transport in the years 2010–2030 [9]. It defines the vision, aims and strategic assumptions for the long-term development of the Malopolska transport system. This is the first such a study prepared by the authorities of the Malopolska Region. Transport Development Strategy takes into account such aims as, for example, increase share of rail in passenger and freight services. To make this possible there must be a significant increase in the quality of rail services by improving the operational parameters of the main transport routes, a parallel improvement in the standard of rolling stock, supporting the construction of the rapid rail integrating Polish metropolises, elimination of "bottlenecks" on lines with high traffic, that is between bigger urban agglomerations, and the replacement and modernization activities. The existing configuration of the transport system is concentrated around Cracow, rail and road transit East-West routes and a number of smaller in terms of number of passengers and quantity of goods North-South connections. In such a situation it is necessary to elaborate a system which ensure more effective access to Cracow and regional clusters of people. This is confirmed by the analysis of social variables, which shows that in the current spatial configuration it is necessary to ensure effective access to the units of education and healthcare, as well as administrative centers [10]. Unfavorable trends such as the acquisition by road transport most of the freight transport, high levels of traffic (especially on the national roads), as well as the constantly growing number of cars do not have a positive influence on transport infrastructure. An additional decrease in passenger rail transport explains the need for change.

Ensuring the competitiveness of road passenger transport and railway transport is one of the criteria for changes. It will require, of course, investments in railway infrastructure and rolling stock, as well as the reduction of rail access rates to infrastructure. Transport Development Strategy for the years 2010–2030 also assumes that it is necessary to adapt the supply of transport services to the changing conditions of their provision, and the size of the demand. Noticeable trend in the movement of the population from the metropolitan areas and surrounding towns requires the protection of the existing infrastructure, but also creation appropriate infrastructures and efficient public transport systems. In addition, the volume of supply of public transport services must be adapted to social and economic goals and assumptions of the spatial development of the region [9, 10]. As seen transport must be taken into account during forecasting socio-economic development, as it is one of the critical factors determining the possibilities and assumptions of the spatial development of the region. Authorities of Malopolska underline that it is necessary to conduct research of the current and the planned distribution of passengers streams and goods, as many decisions on the development of infrastructure (including other than transport), it must be taken from regards to, and based on coherent concept of development of the transport system.

4. RESEARCH METHODS

Cracow is the capital of Malopolska (Poland) and simultaneously it is an important point of cultural and tourist activities. Currently in Cracow lives about 765 thousand people. According to recent studies of the Statistical Office, the number of higher education students in Cracow is about 166 thousand. They represent a large group of residents who creates significant traffic flows in the city and beyond. In this article data from the conducted for this purpose questionnaire surveys relating to interurban traveling has been used. The research include both Internet and direct questionnaire surveys. Taking into account the division into groups of study fields, tested population was a statistical representation of Cracow students (representative sample). Figure 1 shows the real structure of the students number according to groups of fields in 2014/2015 [11]. On the basis of this division the survey has been prepared. Conducted survey included the division into fields of study, as follows (Figure 2):

- economic & administration (also include business studies);
- technical-engineering. (in this group of fields have been included architecture and construction fields and fields related with information and communication technologies);
- social;
- production and processing;
- medical;
- pedagogical;
- humanistic & law (this group include linguistic fields of study);
- others.

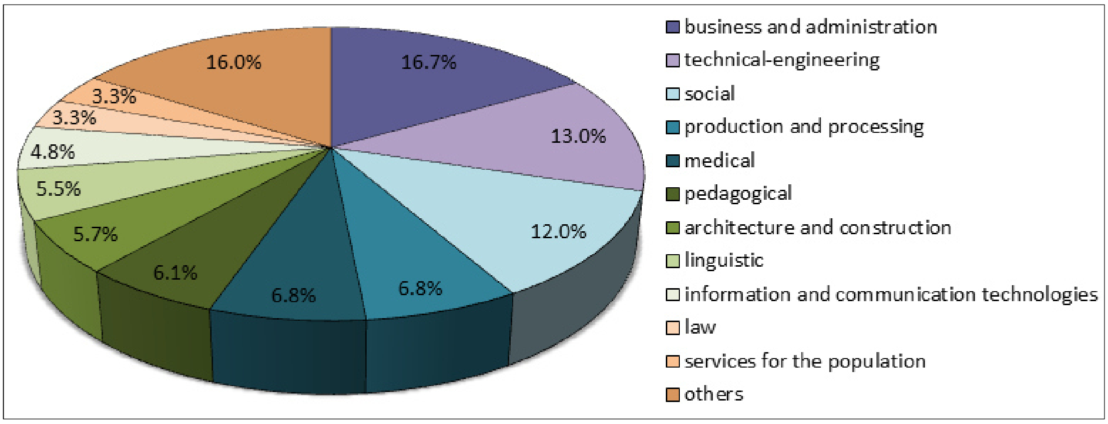


Figure 1 – Structure of the students number according to groups of fields in Malopolska in 2014/2015 [11]

Students answered on a series of questions related to the factors affecting the motivation of the interurban traveling. Questions concerned the aspects of socio-demographic and qualitative aspects determining the choice of the means of transport. Due to the study of interurban travel, the students beyond questions about the chosen mode of transport were asked to indicate which road they use to leave the city. Figure 3 presents the map of Malopolska in which the roads, with corresponding numbers, are marked. Among these roads the respondent made a selection.

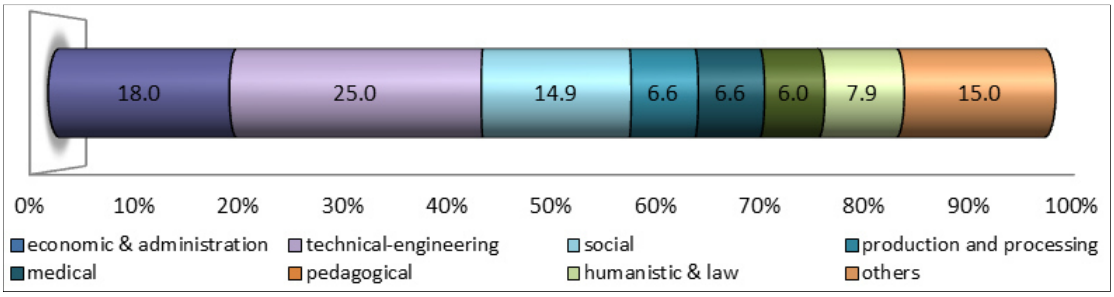


Figure 2 – Structure of the students according to groups of fields in conducted surveys

In the first four tables, 2, 3, 4 and 5, it presents the impact of PM in the four fundamental processes of the model of Nonaka, Toyama & Konno [18]: Socialization, Externalization, Combination and Internalization. In the table 6 the relationship of PM with the Ba will be shown and in the last four tables, 7, 8, 9 and 10, will analyze the impact of the PM in the four above mentioned knowledge assets: Experiential, Conceptual, Systemic and Routine.

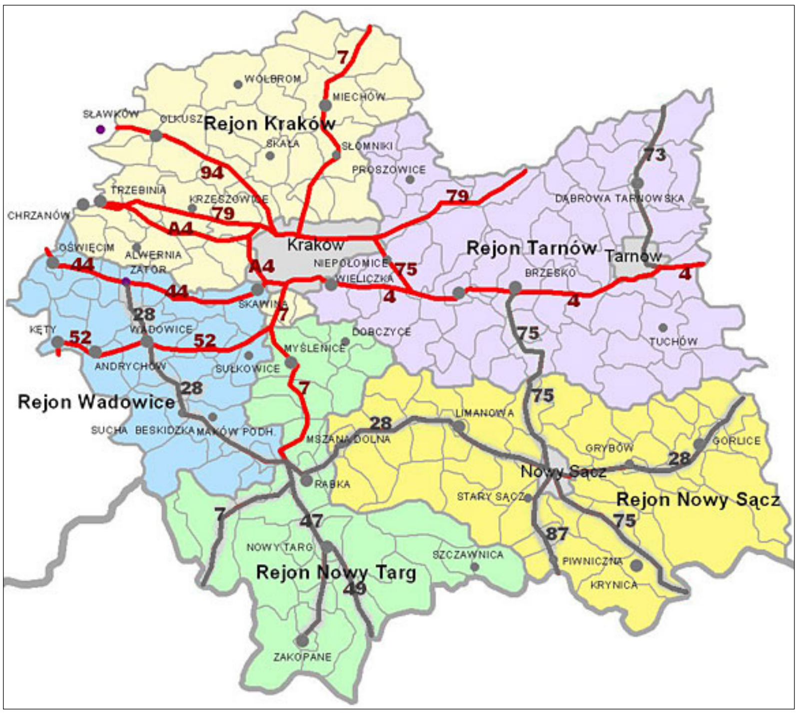


Figure 3 – National roads in Małopolska

5. RESULTS

In order to best illustrate the results, they have been presented in the form of bar (Figure 5) and circular charts (Figure 4). Taking into account the economic aspect should be noted that approximately 31% of the respondents have their own car (Figure 4). Among car owners up to 85% use it to travel a long distance. The percentage distribution of student who participate in the carpooling as driver is only 28% (carpooling means sharing of car journeys so more than one person travels in a car, it means that car driver take passengers), it makes up to 72% of moving cars only with a driver.

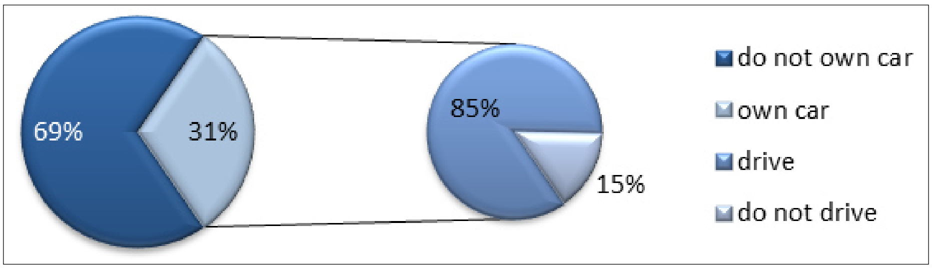


Figure 4 – The percentage distribution of car owners among students in Cracow

Figure 5 shows the percentage share of the most popular means of transport during interurban travels. This diagram takes into account a division into groups of study fields. In total, up to 46.4% of students is traveling by bus, 25.9% choose to travel by car, about 16.3% travel by train, 11.2% choose carpooling.

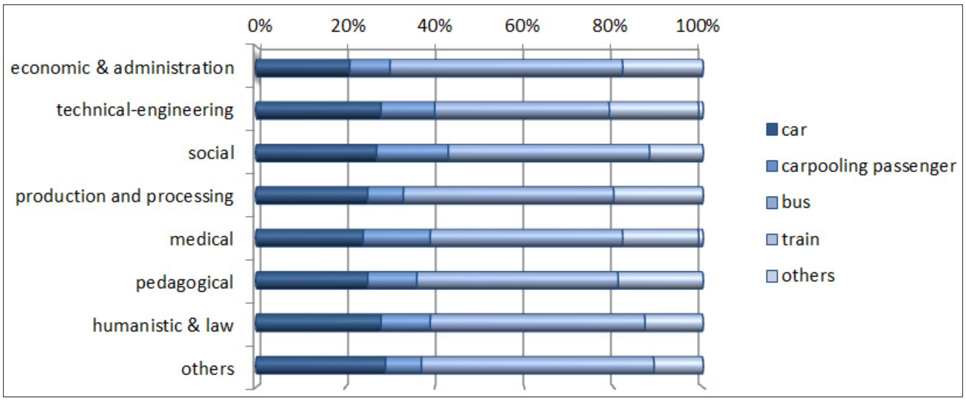


Figure 5 – The percentage share of the most popular means of transport during interurban travels included division into groups of study fields

Figure 6 shows that the most popular roads are route No. 4 (which is part of the motorway A4) and national road No. 7. Road No. 4 enables to connect city with the East and leads in the Tarnow direction, or is one of the possible routes to Nowy Sacz. Up to 37% of the respondents pointed to this road. Another often selected road was national road No. 7. This road travels about 21% of the respondents. It enables connection with Zakopane, and is another possible link with Nowy Sacz.

The surveyed students also assessed a chosen mode of transport in terms of quality. Highest grade they could give was 3, assessment of 2 meant the average grade of a given factor, and the mark 1 was the worst assessment. The results are presented in Table 1. As seen, the best assessed was journey by car. Not only drivers but also carpooling passengers largely gave the highest rating. Only in the case of the financial aspects, car has been the worst evaluated. The situation is slightly better in the case of car-sharing, but the best assessed in financial terms have buses and trains. Unfortunately, these means of transport are relatively low-assessed because of the travel time and distance that must be overcome.

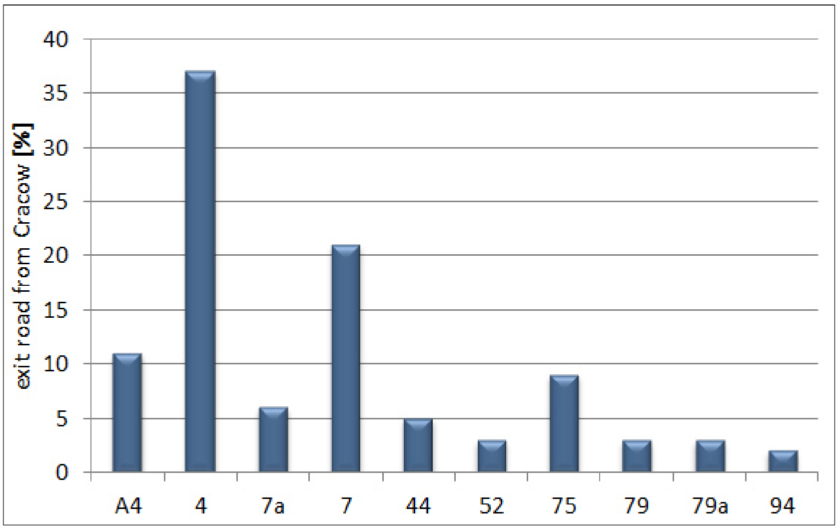


Figure 6 – The percentage share of the most popular exit roads from Cracow among students

Table 1 – Assessment of interurban transport modes among students of Cracow universities

	time	distance	availability	finance	atmospheric conditions	safety	comfort	$\bar{x}$
car	3.0	2.8	3.0	1.2	3.0	2.4	2.8	2.6
carpool	2.1	2.5	2.4	2.4	2.7	2.8	2.8	2.5
bus	1.2	1.5	2.2	2.9	1.5	2.4	2.1	2.0
train	1.1	1.4	1.5	2.8	1.9	3.0	2.5	2.0

6. CONCLUSIONS

Results of conducted questionnaire surveys make it possible to better understand the existing traffic flows. Although students often choose the public transport during intercity travel, it has an average grade. Therefore, improvements especially currently the lowest evaluated travel time and distance that must be overcome, could encourage a greater number of students to choose bus or train instead of the car. It should be remembered that one bus can replace from a few to a dozen cars so even a small number of traveling by car can cause significant traffic congestion. An interesting alternative to public transport can be a carpooling because it can provide comfortable conditions at an affordable price. Despite the high assessments of this form of transport given by students, a small part of them is choosing this mode of transport. This may be caused by the fact that only about 30% of drivers who choose to travel by a car propose a place and take a passengers. However, among the students it may be notice a growing interest in this form of travel. To reduce the share of cars on the roads, not only in the city but also on its outskirts, should be more widely promoted environmentally friendly public transport. Improving the comfort of traveling by bus or train and proposing adequate price and the appropriate promotion of ecological traveling, can significantly affect the choice of transport mode.

7. REFERENCES

[1] *Synteza wyników pomiaru ruchu na drogach wojewódzkich w 2010 roku,* Generalna Dyrekcja Dróg Krajowych i Autostrad, Warszawa, 2011, www.gddkia.gov.pl/userfiles/articles/g/GENERALNY_POMIAR_RUCHU_2010/Synteza2010_dr_woj.pdf, 2016-05-15.

[2] *Synteza wyników GPR 2010,* Generalna Dyrekcja Dróg Krajowych i Autostrad ,Warszawa, 2011, www.gddkia.gov.pl/userfiles/articles/g/GENERALNY_POMIAR_RUCHU_2010/ 0.1.1.5_Synteza_GPR_2010.pdf, 2016-02-15.

[3] Srinivasan, S., Ferreira J.: *Travel behavior at the household level: understanding linkages with residential choice*, Transportation Research Part D, 7(2002), 225–242.

[4] Buehler, R.: *Determinants of transport mode choice: a comparison of Germany and the USA*, Journal of Transport Geography, 2011(in press).

[5] Limanond, T., Butsingkorn T., Chermkhunthod Ch.: *Travel behavior of university students who live on campus: A case study of a rural university in Asia*, Transport Policy 18(2011), 163–171.

[6] Lu, X., Pas E. I.: *Socio-demographics, activity participation and travel behavior*, Transportation Research Part A 33(1999), 1–18.

[7] Newbold, K.B., Scott D.M., Spinney J.E.L., Kanaroglou P., Páez A.: *Travel behavior within Canada's older population: a cohort analysis*, Journal of Transport Geography 13(2005), 340–351.

[8] Nilsson M., Küller R.: *Travel behaviour and environmental concern*, Transportation Research Part D5, 2000, 211–234.

[9] *Strategia rozwoju transportu w województwie Małopolskim na lata 2010–2030*, Departament Transportu i Komunikacji Urząd Marszałkowski Województwa Małopolskiego, Kraków, 2011.

[10] Dyr T.: *Ustawa o publicznym transporcie zbiorowym jako instrument regulacji zawodności rynku przewozów pasażerskich w regionie*, Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 713, Problemy Transportu i logistyki 16(2012).

[11] *Szkolnictwo wyższe w województwie małopolskim w roku akademickim 2014/2015*, Małopolski Ośrodek Badań Regionalnych, Urząd Statystyczny w Krakowie.

LEAN AND GREEN LOGISTICS: A THEORETHICAL FRAMEWORK APPROACH

Tone LERHER[1], Vaska PEJIĆ[1], Borut JEREB[1], Tomaž KRAMBERGER[1], Bojan ROSI[1]

[1]University of Maribor, Faculty of Logistics,
Mariborska cesta 7, 3000 Celje,
Slovenia

Abstract:

Design of new, or redesign of the existing production processes and systems, using the lean philosophy, is becoming one of the most important trend nowadays. In general, the lean philosophy is about the elimination of waste, decrease inventories and manufacturing lead times, which ultimately increases efficiency and reduces costs. Other global trends are environmental protection and energy efficiency initiatives, appeared as green concept. Both mentioned concepts have many mutual characteristics and are often represented as lean & green. The purpose of this paper is to propose a detail systematic literature review on lean logistics, green logistics and the combination of both concepts.

Keywords:

logistics, lean logistics, green logistics, lean and green logistics.

1. INTRODUCTION

Logistics represents an important part of today's businesses and it particularly influences on company's effectiveness and competitiveness [1,2]. Its activities are often identified with a high degree of manual control and human resource management, which greatly affects the execution of operations. The importance of maintaining low costs is of substantial significance; consequently, companies are forced to examine every part of their organization for potential improvements. It is therefore not surprising that in logistics there are many initiatives for possible improvements. We also have to acknowledge that the global logistics costs were estimated at USD 9,177 billion in 2015 [3], so every kind of waste can represent high costs.

One of modern companies' challenges besides eliminating non-value added activities in logistics processes is also assuring sustainable processes. The environmental aspect and ecological consciousness have increased drastically over the last two to three decades, especially in the developed economies. This was shown by Bearing Point research [4], where 35% of global companies noticed that they have incorporated a green supply chain policy in the company's vision. The impact of logistics management within supply chains on environment is vast due to occupying land for transportation and storage, such as transportation access, consuming fuel, transport and storage equipment, generating wastes, producing loss and waste due to distribution processing, consuming material, etc. According to "Internationale Energieagentur" statistics, almost one third of Carbone Dioxide (CO_2) emissions are caused by transport activities which are closely related to logistics activities [5].

Since the area of logistics has rarely been exposed to research on lean and green, the main purpose of this paper represents an analysis of previous research on lean and green paradigms in logistics. The importance of joint research in this case is significant as it is the implementation of such a common system more efficient and has a double effect; it is cost-effective and at the same time ecological. Both paradigms can operate complementary, but often they do not. Lean solutions are sometimes not sustainable, so it is difficult to find an optimal lean and green. However, some researchers state that the adoption practices of lean manufacturing, consequently also lean logistics, will improve the environmental performance of production facilities or in other words, lean is green [6].

2. LEAN LOGISTICS

Lean thinking comes from Toyota manufacturing system [7,8,9] and is also a subject of a work entitled The Machine that Changed the World [10] which highlighted Japanese production methods in comparison to traditional Western mass production systems. Many of the steps required in the factory to physically create a product add little or no value to customers. Mr. Taiichi Ohno, who was one of the beginners of lean thinking and worked in the Toyota Production System (TPS) in the 80's identified seven wastes: production of goods not yet ordered, waiting, rectification of mistakes, excess processing, excess movement, excess transport and excess stock [11,12]. Meanwhile also the new concept – lean logistics – appeared. Womack and Jones [13] state that Toyota was one of the first who saw lean improvements in logistics, especially in the fields or within manufacturing, delivery, ordering, warehouse management, dealers and network structure (Figure 1).

By referring [14], lean logistics is a logistical dimension of lean manufacturing. Its primary objective is to deliver the right materials to the right locations, in the right quantities, and in the right presentation; its second to do all this efficiently. According to [15] lean logistics also takes its fundamental philosophy from the Toyota production system and is based around extended TPS right along supply chains from customers right back to raw material extraction. By referring [16], lean logistics refers to the superior ability to design and administer systems to control movement and geographical positioning of raw materials, work-in-process, and finished inventories at the lowest cost. Leaner processes therefore create value by eliminating wastes in supply chains [17] including the production of goods that have not yet been ordered, waiting time, repairing of errors and excess processing, movements, transport and stock [15].

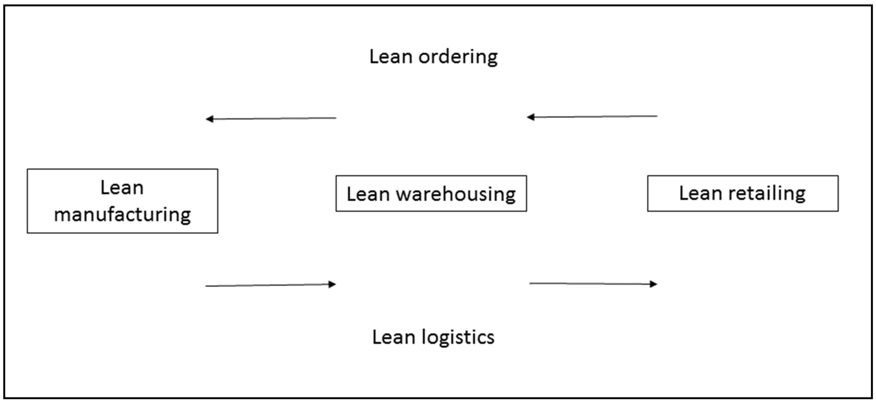


Figure 1 – Lean logistics [15]

Lean logistics systems brought logistics to a new level of efficiency. The latter enables faster delivery of goods to costumers, which in contrast surely affects our environment. It is therefore an inevitable global trend to develop and adopt green logistics management in every sphere of national industry, especially in the production and transport sectors [18,19,20].

3. GREEN LOGISTICS

Eenvironmentalism as the practice of responding to environmental issues in a socially responsible manner has especially in the 90's become increasingly important. It has been characterized as one of the most significant force shaping the economy [21]. Many scientific papers based on concern for the environment have at that time also been written in the field of business and logistics [22,23,24,25,26]. Greening as a competitive initiative has also been discussed in [27]. Their basic reasoning was that investments in greening can be resource saving, waste eliminating and productivity improving. They state that green initiatives could lower not only the environmental impact of a business but also raise efficiency, possibly creating major competitive advantages in innovation and operations.

Skjoett-Larsen [28] wrote a foresight work upon European companies facing new challenges in the next millennium one of which is also green logistics. The author stipulates that within the next five to ten years green supply chains will increasingly dominate the theory and practice in the logistics area. Similar was also indicated by [29] who compared US and non US firms with respect to selected propositions regarding environmental issues, practices and strategies. They have indicated that both firms tend to share similar perspectives and practices regarding the management of environmental logistics and that green concerns will broaden the scope of logistics as well as influence the way that logisticians do their jobs. Moreover, with green logistics a completely new sub-sector of logistics appeared, using new models and tools as green logistics management. The trend is therefore to switch from traditional logistics to green logistics [2].

Later on the popular areas for environmental research involved mostly purchasing related areas as in [30,31,32] and others. At that time there has also been an increased interest in reverse logistics [31,33,34]. Today, modern businesses are facing an increasingly complex legislation with respect to environmental issues. The trust of many of these laws is to place the so called cradle-to-grave (CTG) responsibilities on companies for products and processes. The logistics discipline is well-qualified to deal with these CTG issues because of logistics' focus on supply chain management, which emphasizes the control of materials from suppliers, through value-added processes and on to the customer [35]. Environmentalism appears to have arrived as a key issue facing logistics managers. Leading logistics textbooks now include the green movement [36] and recycling [37] as emerging environmentally logistics issues.

Environment concern is at this time crucial, so we also have to take into account lean logistics which aim is to satisfy customers' needs at the right time and at the right place with at least waste as possible. Modern lean logistics therefore uses sophisticated transport and manipulation equipment, modern technologies on logistics terminals and warehouses to secure lean supply chains. Combining all those elements and developing environmentally – friendly logistics is an issue which has been very topical in recent years. Combining both topics is therefore crucial and will be discussed in the next chapter.

4. LEAN AND GREEN LOGISTICS

Lean is based on the assumption that time contractions reveal hidden quality problems and their solutions lead to improved, cost-effective business processes [38]. The authors further contend that if time contraction implies to lower emissions, then as by the emissions measurements, a lean system is always greener. If the reduction of time does not lead to reduced emissions, it is necessary to find a way or further changes of the lean system to become greener. Ref. [39,40] emphasize that while lean practices can lead to positive environmental contributions, conversely environmental practices often lead to improved lean practices.

A few researchers explore some intersections of these lean and green paradigms [41,42,43,44]. This represents a critical point for companies which are most likely missing opportunities for synergies that are available with improved simultaneous introduction and also may fail in addressing important trade-offs that may occur when there are incompatibilities between strategic initiatives. For example, green and lean strategies can be seen as compatible initiatives because of their common focus on waste removal [45,46,47]. The last conducted a similar study in 2015 using a comprehensive methodology, where author conducted a systematic review of the state of art literature on lean and green. Ref. [45] is of the opinion that due to the wider adoption of lean practices in supply chain and the growing pressure on environmental management companies started to incorporate these environmentally – friendly practices in their own scheme of reducing waste. The implementation of both initiatives, lean and green, has despite the simplicity intended to illustrate the potential synergies and conflicts that arise when we implement any combination of green or lean. The combination of both paradigms adds management complexity of logistics of a certain company. There also must not be overlooked the obstacles when we want to rearrange logistics according to principles of green and lean, including the lack of ecological awareness [41], a general default principle that ecologic does not pay off [48], and the perception that green initiatives are time consuming and expensive.

By referring [49], only a handful of environmental experts examined the relationships between the various aspects of lean and green practices. It is argued [27] that there is an issue about two completely different things, but some experts have recognized their possible cooperation. By referring [50] a green as a public good blending of lean interprets these positive side effects as efforts to reduce waste and reducing pollution. Many companies have a natural tendency to move towards green practices. Generally speaking, most of research concerning the link between lean and green touch the efficient use of energy and resources and lower waste and pollution [50,51,52,53]. Some companies are therefore resisting the implementation of environmental initiatives because they can be time consuming and expensive [27]. Lean production and mass adaptation need more settings that generate more waste and consume more energy [50]. Changing production technologies which would produce more environmentally responsible processes and products require a lot of pre-investment for which the return is not necessarily yield realized in the short term, as with the lean cost-declining strategies [41].

Improvements in production systems can lead to direct and indirect benefits for environmental management, often in the form of reduction of waste [54]. The objectives set to achieve leanness thus become a catalyst for a successful implementation of green practices and also help to achieve the desired objectives [50,51]. By referring [49], the intersection of lean and green paradigms in supply chain found a cross-section in the following parameters: management techniques and lowering waste, people and organization, reducing delivery time, key performance indicator: the level of service, and also a set of common tools and practices that they share. The main common point is in the objective of disposing of waste of both paradigms. Nevertheless, a waste of both paradigms is defined otherwise but both respectively target the removal of excess: the waste in the broadest sense. Lean logistics is focusing on removing 8 wastes related to efficient flow, while green logistics is focusing on green wastes in the form of inefficient use or waste production [6,45,55]. Despite the fact that these two paradigms have different goals for the removal of waste, they respectively target the same type of waste, in particular, storage, transport and production or outputs which are not products [49].

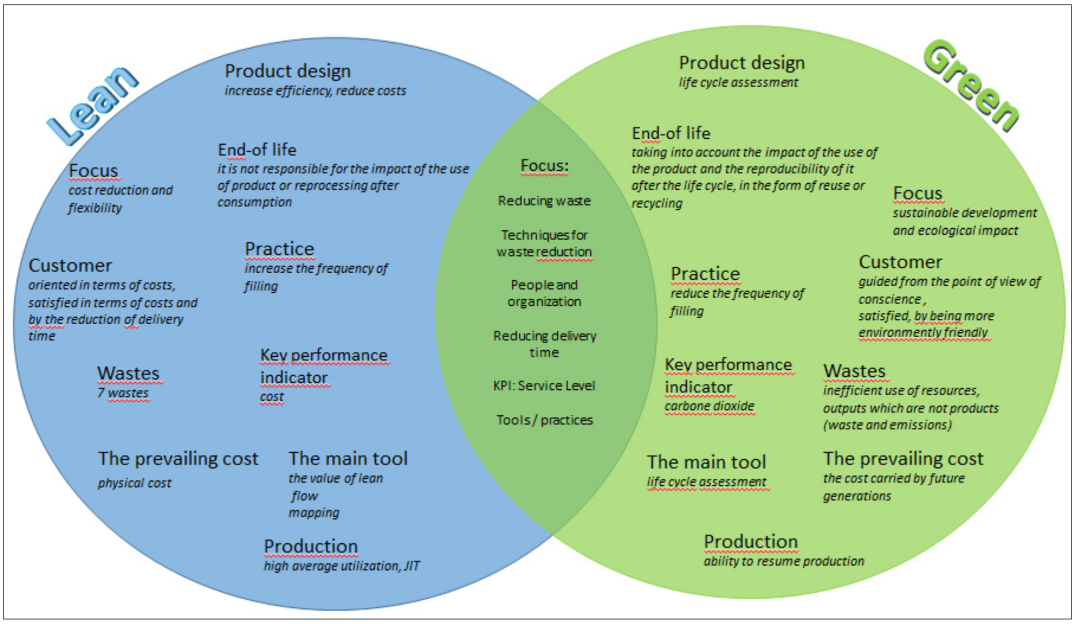


Figure 2 – Common parameters of a lean and green paradigm [49]

5. DISCUSSIONS

Based on the lean and green logistics concept, both practices (lean and green) can help businesses become efficient. The most significant wastes in lean philosophy (related to the inventory, transport operations, space, equipment utilization, etc.) are deeply engaged with the logistics. In industrial facilities (plants, distribution centers, warehouses) logistics plays a significant role. In order to reduce the costs of logistics (the cost of logistics could range up to 20% of the total cost of the product; based on the type of industry), while simultaneously increase customer service, new ways of designing logistics processes and systems are needed. If the logistics is about managing inventory and operating the internal transport, warehousing and packaging, the lean is about speed, continuous flow and elimination of waste. Therefore, the impact of the lean philosophy on the logistics is extremely significant and recognized with the emergence of the lean logistics concept. Although lean philosophy already has some impact on greening by reducing resource and energy use, various technologies and green approaches should be also taken into account: from the engineering solutions like solar power, wind power, geo-thermal power, efficient lighting, heating and cooling of buildings, to the new developed intralogistics systems (material handling equipment and systems) with emphasis to the i.e. efficient drives and fuel savings, CO_2 reductions, recyclable materials used, regenerative breaking, reduced needed space, etc., recognized with the emergence of the green logistics concept. As already mentioned, along with the economic and environmental issues, third aspect not to be forgotten in achieving more sustainable intralogistics is social aspect. This is usually considered with safety and ergonomic features of implemented intralogistics systems (equipment and workplaces).

The above explained requirements for new logistics systems are already recognized by solution providers (industry of logistics systems), who are offering new logistics systems and equipment named as lean & green or sustainable solutions.

To summarize, only when both concepts lean and green are implemented simultaneously, they can disclose their full potential and make a greater contribution than if they were implemented separately.

6. CONCLUSIONS

In this paper, a detail literature review analysis on lean logistics, green logistics and both lean and green logistics is presented.

The research itself deals with many scientific papers closely related to all three topics. The analysis identifies benefits in the fields of lean logistics, green logistics and indicates different ways of thinking about the possible interaction of the two concepts (lean and green logistics). It is evident that for each concept quite a reasonable research has been done, however a great interest from the industry on the green and lean logistics topic have been noticed, as well.

The proposed literature review could present a starting point for future research on how to incorporate both concepts (lean and green logistics) efficiently together.

It is believed that (lean and green) concepts in logistics will indubitably bring changes into planning of industrial facilities and will mean great challenge for those who are engaged in the industrial engineering research area.

7. REFERENCES

[1] Christopher, M.: *Logistics & Supply Chain Management*. Pearson Education Limited, 1992.

[2] Beškovnik, B., Twrdy E.: *Green logistics strategy for South East Europe: to improve intermodality and establish green transport corridors*, Transport, 27(2015), 25–33.

[3] Armstrong, I.: *Global and Regional Infrastructure, Logistics Costs, and Third-Party Logistics Market Trends and Analysis*, Armstrong & Associates, INC., 2014.

[4] Supply Chain Monitor. How Mature is the Green Supply Chain, 2008.

[5] Kranke, A.: *Effizienz statt Leistung*; Logistik Inside, 2008.

[6] King, A.A., Lenox, M.J.: *Lean and green? An empirical examination of the relationship between lean production and environmental performance*, Production and Operations Management, 2001.

[7] Monden, Y.: *The Toyota Production System*, Productivity Press, 1983.

[8] Shingo, S.: *Study of the Toyota Production Systems*, Japan Management Association, 1981.

[9] Ohno, T.: *The Toyota Production System: Beyond Large-Scale*, Production Productivity Press, 1988.

[10] Womack, J., Jones D.T., Roos, D.: *The Machine That Changed the World*, Rawson Associates, 1990.

[11] J.M. Association. *Kanban: Just-in-time at Toyota*, Productivity Press, 1985.

[12] Monden, Y.: *Toyota Production System: An Integrated Approach to Just-In-Time*, 2nd Edition; Industrial Engineering and Management Press, 1993.

[13] Womack, J., Jones D.T.: *Lean Thinking: Banish Waste and Create Wealth for Your Corporation*, Simon and Schuster, 1996.

[14] Baudin, M.: *Lean Logistics: The Nuts and Bolts of Delivering Materials and Goods*, Productivity Press, 2004.

[15] Jones, D.T., Hines P., Rich N.: *Lean logistics*, 1997, 153–173.

[16] Bowersox, D., Closs D.J., Cooper M.B.: *Supply Chain Logistics Management*, McGraw-Hill, 2002.

[17] Günthner, W.A., Tenerowicz P.: *Paths toward greater energy-efficient intra logistics*, 2010.

[18] Dunning, J.H., Fortanier F.: *Multinational enterprises and the new development paradigm: consequences for host country development*. Multinational Business Review, 15(2007), 25–46.

[19] Carter, C.R., Rogers D.S.: *A framework of sustainable supply chain management: moving toward new theory*, International Journal of Physical Distribution and Logistics Management, 38(2008), 360–387.

[20] Kovács, G.: *Corporate environmental responsibility in the supply chain*, Journal of Cleaner Production, 16(2008), 1571–1578.

[21] Murphy, P.R., Poist R.F., Braunschweig C.D.: *Role and relevance of logistics to corporate environmentalism*, International Journal of Physical Distribution and Logistics, 25(1995), 5–19.

[22] Kroon, L., Vrijens G.: *Returnable containers: an example of reverse logistics*, International Journal of Physical Distribution & Logistics Management, 25(1995), 56–68.

[23] Murphy, P.R;, Poist R.F.; Braunschweig C.D.: *Management of environmental issues in logistics: current status and future potential*, Transportation Journal, 34(1994), 48–56.

[24] McKinnon, A., Cullinane S., Browne M., Whiteing A.: *Green Logistics: Improving the Environmental Sustainability of Logistics*; London: Kogan, 2010.

[25] Wu, H., Dunn S.C.: *Environmentally responsible logistics systems*, International Journal of Physical Distribution & Logistics Management, 25(1995), 20–38.

[26] McIntyre, K., Henham A., Pretlove J.: *Logistics Performance Measurement and Greening Supply Chains: Diverging Mindset*, The International Journal of Logistics Management, 9(1998), 57–68.

[27] Porter, M.E., Van der Linde C.: *Green and competitive: ending the stalemate*, 1995, 120–134.

[28] Skjoett-Larsen, T.: *European logistics beyond 2000*, International Journal of Physical Distribution & Logistics Management, 30(2000), 377–387.

[29] Murphy, P.R., Poist R.F.: *Green Perspectives and Practices: a "comparative logistics" study*, Supply Chain Management: An International Journal, 8(2003), 122–131.

[30] Min, H., Galle W: *Green purchasing strategies: trends and implications*, International Journal of Purchasing and Materials Management, 1997, 10–17.

[31] Carter, C., Ellram L., Ready J.: *Environmental purchasing: benchmarking our German counterparts*, International Journal of Purchasing and Materials Management, 34(1998), 28–38.

[32] Carter, C., Dresner M.: *Purchasing's role in environmental management: cross-functional development of grounded theory*, Journal of Supply Chain Management, 37(2001), 12–26.

[33] Stock, J.R.: *Reverse Logistics – A White Paper prepared for the Council of Logistics Management*. Council of Logistics Management, Oak Brook, IL, 1992.

[34] Goldsby, T., Closs, D.: *Using activity-based vosting to reengineer the reverse logistics channel*, International Journal of Physical Distribution & Logistics Management, 30(2000), 500–514.

[35] Marchet, G., Melacini M., Perotti, S.: *Environmental sustainability in logistics and freight transportation*, Journal of Manufacturing Technology Management, 25(2014), 775–881.

[36] Kumar, V., Holt D., Ghobadian A., Garza-Reyes J.A.: *Developing green supply chain management taxonomy-based decision support system*, International Journal of Production Research, 53(2014), 1–18.

[37] Tacken, J., Sanchez Rodrigues V.S., Mason R.: *Examining CO2 reduction within the German logistics sector*, The International Journal of Logistics Management, 25(2014), 54–84.

[38] Venkat, K., Wakeland W.: *Is Lean Necessarily Green?* Proc. of the 50th Annual Meeting of the International Society for the Systems Sciences, 2006.

[39] Karp, H.R.: Green Suppliers Network: Strengthening and Greening the Manufacturing Supply Base, 2005, 37–46.

[40] Bergmiller, G.G., McCright, P.R.: *Lean Manufacturers' Transcendence to Green Manufacturing*, 2009 Industrial Engineering Research Conference, 2009.

[41] Mollenkopf, D., Stolze H., Tate W.L., Ueltschy M.: *Green, lean and global supply chains*, 2009, 14–41.

[42] Cabrala, I., Cruz-Machada G.A.: *A Decision-Making Model for Lean, Agile, Resilient and Green Supply Chain Management*, International Journal of Production Research, 50(2012).

[43] Banawi, A., Bilec M.M.: *A framework to improve construction processes: Integrating Lean, Green and Six Sigma*, International Journal of Construction Management, 14(2014), 45–55.

[44] Garza-Reyes, J.A.: *Lean and green – a systematic review of the state of art literature*, Journal of Cleaner Production, 102(2015), 18–29.

[45] Kleindorfer, P.R., Singhal K., Van Wassenhove L.N.: *Sustainable Operations Management*, Production & Operations Management, 2005, 482–492.

[46] Verrier, B., Rose B., Caillaud E., Remita H.: *Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository*, Journal of Cleaner Production, 2014, 83–93.

[47] Garza-Reyes, JA.: *Lean and green – a systematic review of the state of art literature*, Journal of Cleaner Production, 2015, 18–29.

[48] Disney, S.M., Naim M.M., Towill D.R.: *Dynamic simulation modelling for lean logistics*, 1997, 174–196.

[49] Rothenberg, S., Pil F., Maxwell J.: *Lean, green, and the quest for environmental performance*, 2001, 228–243.

[50] Dües, C.M., Tan K.H., Lim M.: *Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain*, 2013, 93–100.

[51] Simpson, D., Mason, R.: *Environmental and Transport Supply Chain Evaluation with Sustainable Value Stream Mapping*, 7th Logistics Research Network Conference, 2002.

[52] Hansen, J.D., Melnyk S.A., Calantone R.: *Core values and environmental management: a strong interface approach*, Greener Management International, 46(2004), 29–40.

[53] Larson, T., Greenwood R.: *Perfect complements: synergies between lean production and eco-sustainability initiatives*, Environmental Quality Management, 13(2004), 27–36.

[54] Simpson, D.F., Power D.J.: *Use the supply relationship to develop lean and green suppliers*, 2005, 60–80.

[55] EPA. *The Lean and Environment Toolkit*, Version 1.0. 2007. URL: http://outsourced-http://www.epa.gov/lean/, 2015-01-05.

SIMULATION-BASED PERFORMANCE ANALYSIS OF ORDER PICKING SYSTEMS

Tone LERHER[1], Valerij STRMČNIK[1], Iztok POTRČ[1], Matjaž ŠRAML[2], Boris JERMAN[3], Nenad ZRNIĆ[4]

[1]University of Maribor, Faculty of Logistics,
Mariborska cesta 7, Celje,
Slovenia
[2]University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture,
Smetanova ulica 17, Maribor,
Slovenia
[3]University of Ljubljana, Faculty of Mechanical Engineering,
Aškrčeva 6, Ljubljana,
Slovenia
[4]University of Belgrade, Faculty of Mechanical Engineering,
Kraljice Marije 16, Belgrade,
Serbia

Abstract:

Order picking is the process of retrieving items from the warehouse in response to a specific customer request. The design of an order picking system is often complicated and complex due to a large spectrum of external and internal factors, which influence the design choices. The most common objective of order picking systems during the design phase is to maximize the service level subject to reduce constraints such as labour, machines and capital. Therefore, the main objective of our paper is to present different policies for routing order pickers in one-block warehouse. Regarding the proposed routing policies, the effects on the order picking system performance will be presented.

Keywords:

warehouses, order picking, routing policies, efficiency analysis

1. INTRODUCTION

Order picking is the process of retrieving items from storage locations in response to specific customer's orders. It is identified as the most labour intensive and costly activity for almost every warehouse. The cost of order picking is estimated to be as much as 55% of the total warehouse operating cost [1]. Consequently, warehousing professionals consider order picking as the most prominent area of productivity improvements with the objective of reducing the operating costs in warehouses.

Various types of order picking systems can be found in warehouses and often several order picking systems are used within one warehouse. The majority of warehouses use low- or high-level picker-to-parts systems, where the order picker walks or drives along the picking aisles to pick (collect) items. The most common objective of designing order picking systems is to maximize the service level subject to reduce constraints such as labour, machines and capital.

The efficiency of the order picking system is influenced greatly by using a proper routing policy, storage method, order batching method and warehouse layout. Many scientific papers [1–14] have been published until now in the order picking research area.

The main objective of our paper is to present different policies for routing order pickers, with the objective of minimizing the average travel distance (or equivalently minimizing the total cost, which may include both investment and operational costs).

In the remainder of this paper is the following. Section 2 briefly explains order picking with routing policies, storage methods, order picking methods and warehouse layouts. Analysis of results with discussion is presented in Section 3. Comments on results and possible ways of further research are given at the end of the paper in Conclusion.

2. ORDER PICKING

2.1. Routing policies

A proper routing planning can minimize the overall order picking costs and lead to a high picking performance. There are several routing policies developed and used in practice. They range from the very simple to the slightly more complex. The performance of these heuristics depends on the particular operating conditions of the system under study due to their definitions [4].

In literature and in practice the following routing policies are used (see Figure 1):

- S-shape policy
- The simplest routing heuristic is S-shape policy. When this policy is used, the order picker enters every aisle where an item has to be picked and traverses the entire aisle. Aisles where nothing has to be picked are skipped. An exception is made for the last aisle visited in case the number of aisles to be visited is odd. In that case a return travel is performed in last aisle visited [4].
- Return policy
- Another relatively simple routing heuristic is Return policy. Order-picker enters and leaves aisles containing item(s) to be picked from the front aisle [4].
- Midpoint policy
- Midpoint routing policy, also one simple heuristics, looks like return policy on two halves of a warehouse. Only first and last aisle visited are traversed entirely [4].
- Largest gap policy
- With Largest Gap policy all aisles that contain even one item to be picked are also left at the same side as they were entered, except the first and last visited which are traversed entirely. The gap represents the separation between any two adjacent picks, between first pick in the aisle and front aisle, or between the last pick in the aisle and the back aisle. If the largest gap is between two adjacent picks, the picker performs a return route from both ends of the aisle. Otherwise, a return route from either the front or back aisle is used. The largest gap is therefore the portion of the aisle that the order picker does not traverse. This policy is slightly more complex routing heuristic than the first three mentioned [4].
- Combined policy
- Combined policy is a combination of S-shape and Return policies with a small component of dynamic programming, which gives it a possibility to look one aisle ahead [4].
- Optimal policy
- Optimal policy is a combination of all policies with an expressive component of dynamic programming that gives it a possibility to look aisles ahead [4].

For a detail explanation of the above-mentioned heuristics see web site http://www.roodbergen.com/.

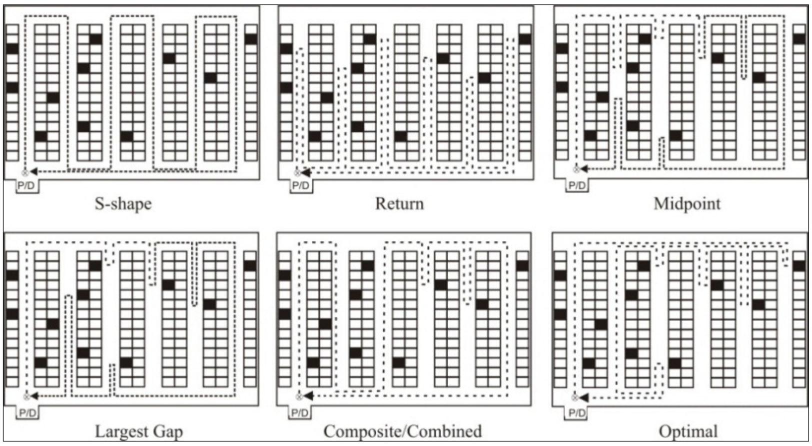


Figure 1 – Examples of order picking policies [4]

2.2. Storage methods

Storage methods assign items to warehouse storage locations, based on popularity, demand, size, etc. (see Figure 2). In order-picking systems, storage methods are usually based on rule of assigning the frequently accessed items to the locations near depot P/D point [4].

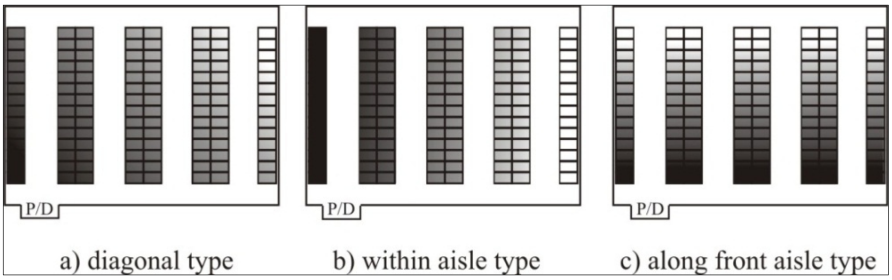


Figure 2 – Examples of volume based storage [4]

2.3. Order-picking methods

Methods of organization of order-picking, called also pick strategies, determine how orders are picked in warehouses.

In literature and in practice the following order-picking methods are used [13]:

- Discrete picking;
- Zone picking;
- Batch picking;
- Wave picking;
- Zone-Batch picking;
- Zone-Wave picking;
- Zone-Batch-Wave picking.

2.4. Warehouse layouts

Traditional order-picking area (warehouse) layouts can be found in majority of warehouses. The basic form is with parallel aisles, a central depot (P/D point), and two possibilities for changing aisles, at the front and at the rear of warehouse (see Figure 3 left). Modifications of this basic form are usually with adding one or more additional cross aisles. In this case we refer to a layout with multiple cross-aisles. The layout with one middle cross aisle is shown in Figure 3 right [5].

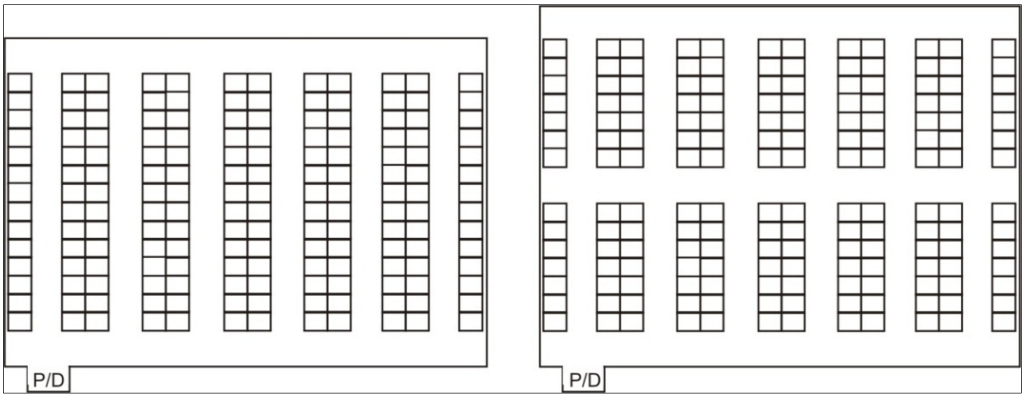


Figure 3 – Examples of warehouse layouts [5]

3. ORDER-PICKING SYSTEM UNDER STUDY

In this section, main input data for the simulation analysis are provided and discussed. For the efficiency analysis of the selected order-picking system, simulation software from K.J. Roodbergen has been used (see web site http://www.roodbergen.com/).

Table 1 – Warehouse layout configurations

Warehouse layout	Warehouse width (m)	Warehouse length (m)	Number of racks	Number of aisles	Number of locations per rack	Warehouse volume
1	20	20	10	5	16	160
2	24	24	12	6	20	240
3	28	28	14	7	24	336
4	32	32	16	8	28	448
5	36	36	18	9	32	576
6	40	40	20	10	36	720
7	44	44	22	11	40	880
8	48	48	24	12	44	1056

Note: Warehouse layout configurations are selected according to the references of warehousing producers and practical experiences of the authors.

The simulation was conducted on eight selected (8) one-block warehouse layouts with different number of locations per warehouse (see Table 1). Due to the simplicity of distance calculation, dimension of a surface is 1 m^2 (w = 1 m · l = 1 m) and the centre distance between aisles d = 4 meters. Depot P/D point was set on the left side of the warehouse. Number of lines per order/per travel n was set to n_1 = 10, n_2 = 20, n_3 = 30, n_4 = 40 and n_5 = 50 items. Simulations were conducted for the next routing policies: S-shape policy, Largest gap policy, Combined policy, and Optimal policy.

4. RESULTS

In this section, average travel distances according to selected routing policies, order sizes and warehouse layouts are presented. The analysis was performed by considering warehouse layouts (see Table 1).

4.1. Performance of routing policies

Average travel distances according to selected routing policies, order sizes and warehouse layouts, are given on the basis of the performed analysis. Analysis was conducted for the selected warehouse layouts presented in Table 1. In order to receive the most representative results, the simulation was set to 1000 individual runs. Tables 2–5 summarize average travel distances for different routing policies, order sizes and warehouse layouts.

Table 2 – Average travel distance for “S-shape” policy

Warehouse layout	Average travel distance (m)				
	n_1 = 10	n_2 = 20	n_3 = 30	n_4 = 40	n_5 = 50
1	104.70	118.90	122.70	124.10	124.90
2	141.10	158.20	159.70	160.00	160.00
3	180.30	214.80	226.50	231.40	233.30
4	221.00	269.10	278.20	279.70	280.00
5	260.30	327.80	354.00	365.10	371.30
6	304.60	392.10	421.00	429.60	431.30
7	348.00	458.10	502.30	525.10	536.50
8	391.80	527.90	584.80	605.70	613.10

Table 3 – Average travel distance for “Largest gap” policy

Warehouse layout	Average travel distance (m)				
	n_1 = 10	n_2 = 20	n_3 = 30	n_4 = 40	n_5 = 50
1	93.60	112.60	122.40	128.20	132.30
2	122.30	153.80	170.50	181.40	188.70
3	151.80	197.10	222.30	239.00	250.50
4	182.10	242.20	278.50	302.80	319.20
5	211.60	286.90	335.20	367.90	391.80
6	242.50	333.20	395.00	436.90	468.00
7	273.10	381.20	456.30	508.90	549.00
8	303.50	428.90	518.70	583.40	632.10

Table 4 – Average travel distance for "Combined" policy

Warehouse layout	Average travel distance (m)				
	$n_1 = 10$	$n_2 = 20$	$n_3 = 30$	$n_4 = 40$	$n_5 = 50$
1	97.70	111.80	117.60	119.90	121.50
2	129.10	153.00	158.50	159.80	160.00
3	161.90	199.10	212.90	220.00	223.90
4	195.80	248.20	269.30	277.10	279.30
5	228.40	298.60	329.90	344.10	353.00
6	263.80	350.70	393.30	414.80	425.00
7	299.30	406.00	461.00	490.30	506.50
8	334.30	461.60	531.20	570.10	592.10

Table 5 – Average travel distance for "Optimal" policy

Warehouse layout	Average travel distance (m)				
	$n_1 = 10$	$n_2 = 20$	$n_3 = 30$	$n_4 = 40$	$n_5 = 50$
1	84.80	103.00	109.10	111.00	111.60
2	110.50	140.30	152.20	156.90	158.70
3	136.90	179.50	199.10	208.20	212.20
4	163.80	221.30	250.40	265.40	272.40
5	190.00	262.50	302.70	324.60	336.90
6	218.10	305.60	358.10	388.40	406.20
7	245.60	350.60	415.10	455.10	480.40
8	272.80	394.70	473.30	524.00	556.10

Table 6 – Average relative difference of distances for selected routing policies

Order size	Average relative difference of distances			
	S-strategy (%)	Largest gap (%)	Combined (%)	Optimal (base)
$n_1 = 10$	134.97	111.01	119.43	100
$n_2 = 20$	123.38	109.24	112.74	100
$n_3 = 30$	115.17	110.96	108.56	100
$n_4 = 40$	110.55	113.62	106.16	100
$n_5 = 50$	107.97	116.52	104.88	100

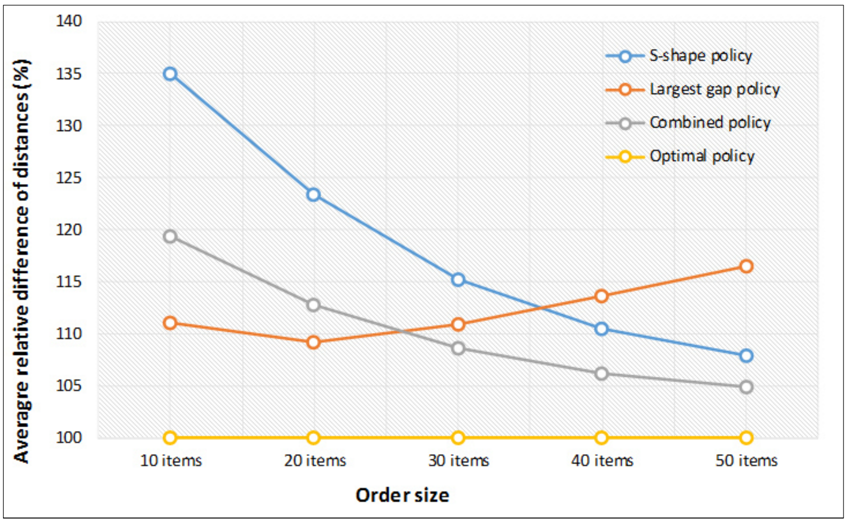


Figure 4 – Average travel distances in relation to lines per order and routing policies

The graph in Figure 4 shows the performances of routing policies depending on the order size (lines per order) for average relative difference of distances for all examined warehouse layouts. According to the distribution of the Optimal routing policy (base), the S-shape routing policy is relatively close to other strategies in the case of a large order size, but does not perform well with relatively small order size. In contrast, the Largest Gap policy performs well with small order size, while it is not so efficient in the case of a large order size. The Combined policy is, in general the best heuristic policy for small and large order size.

According to order size, relatively small differences are noticed within all routing policies. For this reason, the relationship between the routing policies and the warehouse layouts will be shown in continuation (see Table 7 and Figure 5).

Table 7 – Average travel distance and average relative difference of distances for the selected routing policy

Warehouse layout	S-strategy (m)	Average relative difference (%)	Largest gap (m)	Average relative difference (%)	Combined (m)	Average relative difference (%)	Optimal (m)	Base
1	119.06	114.59	117.82	113.40	113.70	109.43	103.90	100
2	155.80	108.41	163.34	113.65	152.08	105.82	143.72	100
3	217.26	116.07	212.14	113.33	203.56	108.75	187.18	100
4	265.60	113.19	264.96	112.91	253.94	108.22	234.66	100
5	335.70	118.48	318.68	112.47	310.80	109.69	283.34	100
6	395.72	118.03	375.12	111.88	369.52	110.21	335.28	100
7	474.00	121.74	433.70	111.39	432.62	111.11	389.36	100
8	544.66	122.62	493.32	111.06	497.86	112.09	444.18	100

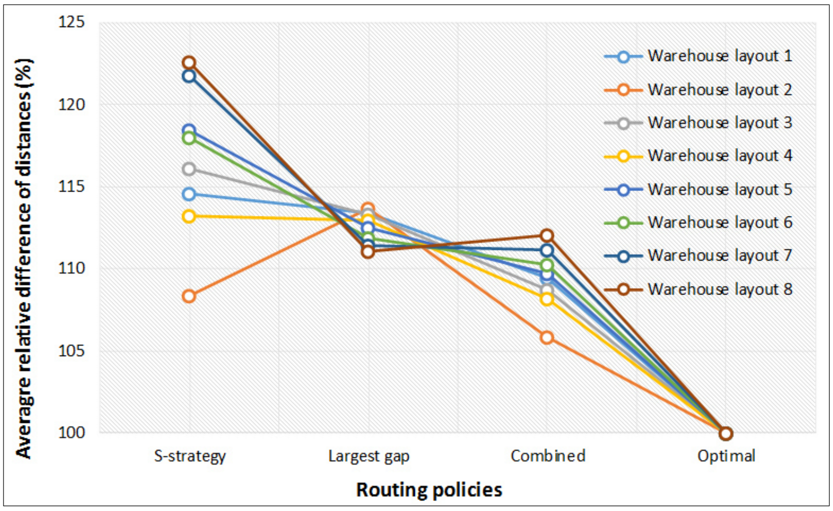


Figure 5 – Average travel distances in relation to warehouse layouts and routing policies

The graph in Figure 5 shows the performances of routing policies depending on the examined warehouse layout for average relative difference of distances of all order sizes. According to the distribution of average relative difference of distances, the S-shape routing policy performs well in the case of relatively small warehouse layouts (Warehouse layout 2), but does not perform well within larger warehouse layouts. In contrast, the Largest Gap policy and the Combined policy perform well with small, medium and large warehouse layouts.

4.2. Performance of routing policies with ABC zoning

Average travel distances according to selected routing policies, order sizes, warehouse layouts and ABC zoning, are given on the basis of the performed analysis (see Tables 7–10). The simulation analysis included three different ABC zones, denoted as 80/20, 15/30, 5/50 (the first number indicates the percentage of the total activity corresponding to size of zones indicated in the percentage by the second number). In our analysis the pattern of ABC zones presented in Figure 6, was used. Analysis was conducted for the selected warehouse layouts presented in Table 1, In order to receive the most representative results, the simulation was set to 1000 individual runs.

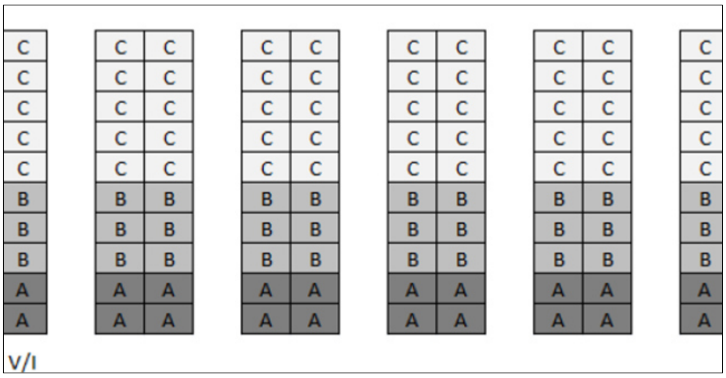


Figure 6 – Pattern of ABC zones

Table 8 – Average travel distance for "S-shape" policy and ABC zoning

Warehouse layout	Average travel distance (m)					
	$n_1 = 10$	$n_2 = 20$	$n_3 = 30$	$n_4 = 40$	$n_5 = 50$	Average distance
1	112.20	125.20	127.30	127.60	127.70	124.00
2	148.20	159.40	160.00	160.00	160.00	157.52
3	188.30	225.10	235.70	238.50	239.20	225.36
4	230.80	273.30	279.50	279.90	280.00	268.70
5	272.30	339.00	367.40	377.40	381.20	347.46
6	317.90	402.80	427.30	431.30	431.90	402.24
7	362.70	469.40	517.00	540.50	550.90	488.10
8	408.30	540.00	594.20	611.80	615.30	553.92

Table 9 – Average travel distance for "Largest gap" policy and ABC zoning

Warehouse layout	Average travel distance (m)					
	$n_1 = 10$	$n_2 = 20$	$n_3 = 30$	$n_4 = 40$	$n_5 = 50$	Average distance
1	77.70	89.80	97.50	102.90	107.40	95.06
2	99.30	117.60	129.70	138.80	146.10	126.30
3	121.10	146.40	163.70	176.80	187.20	159.04
4	142.90	175.50	199.10	216.50	231.10	193.02
5	164.90	204.70	234.30	256.80	275.60	227.26
6	186.70	234.40	270.80	299.40	322.80	262.82
7	208.40	265.10	308.30	342.70	370.50	299.00
8	230.90	294.80	345.20	385.70	420.00	335.32

Table 10 – Average travel distance for "Combined" policy and ABC zoning

Warehouse layout	Average travel distance (m)					
	$n_1 = 10$	$n_2 = 20$	$n_3 = 30$	$n_4 = 40$	$n_5 = 50$	Average distance
1	83.70	97.90	104.20	108.30	111.50	101.12
2	107.50	129.80	140.70	147.50	152.00	135.50
3	132.50	163.70	180.60	191.40	199.00	173.44
4	156.70	197.40	221.80	237.70	249.10	212.54
5	182.10	232.70	264.70	286.20	302.10	253.56
6	207.10	268.50	309.20	337.70	359.40	296.38
7	231.40	304.90	354.70	389.60	416.50	339.42
8	257.10	341.40	401.00	443.90	478.90	384.46

Table 11 – Average travel distance for "Optimal" policy and ABC zoning

Warehouse layout	Average travel distance (m)					
	$n_1 = 10$	$n_2 = 20$	$n_3 = 30$	$n_4 = 40$	$n_5 = 50$	Average distance
1	60.30	75.90	86.00	92.90	97.90	82.60
2	76.50	98.70	113.40	124.50	132.40	109.10
3	93.10	122.10	142.40	157.60	168.50	136.74
4	109.70	145.80	171.90	192.20	207.60	165.44
5	126.00	170.00	202.00	227.60	247.20	194.56
6	142.80	194.30	233.10	264.30	289.10	224.72
7	159.20	219.50	265.20	302.50	331.30	255.54
8	176.20	244.00	296.90	340.50	375.90	286.70

Table 12 – Average travel distance with average relative difference of distances for selected routing policy with ABC zoning

Warehouse layout	S-strategy (m)	Average relative difference (%)	Largest gap (m)	Average relative difference (%)	Combined (m)	Average relative difference (%)	Optimal (m)	Base
1	124.00	150.12	95.06	115.08	101.12	122.42	82.60	100
2	157.52	144.38	126.30	115.77	135.50	124.20	109.10	100
3	225.36	164.81	159.04	116.31	173.44	126.84	136.74	100
4	268.70	162.42	193.02	116.67	212.54	128.47	165.44	100
5	347.46	178.59	227.26	116.81	253.56	130.32	194.56	100
6	402.24	179.00	262.82	116.95	296.38	131.89	224.72	100
7	488.10	191.01	299.00	117.01	339.42	132.82	255.54	100
8	553.92	193.21	335.32	116.96	384.46	134.10	286.70	100

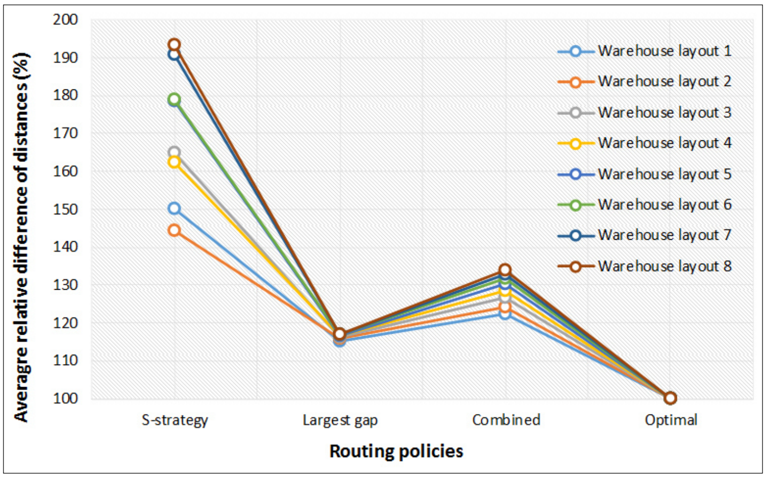


Figure 7 – Average travel distances in relation to warehouse layouts, routing policies and ABC zoning

According to the diagram in Figure 7, large savings are possible in the case of using ABC zoning (see Table 7 and Table 12), except for the S-shape routing policy. In general, all routing policies with ABC zoning outperform routing policies that are based on random policy. The later has a high impact on throughput performance of the order picking systems, which means that fewer order pickers are needed or that we are capable to execute more shipments to satisfy customers' orders.

5. CONCLUSIONS

In this paper the order picking system with different routing policies, is presented. In general, the existent routing policies deal with routing order picker in the picker-to-parts systems with the objective of minimum travel distance. In the case of warehouse with more aisles and large pick list sizes, the application of selected routing policy becomes questionable and could in some cases result in near optimal routes. According to the analysis, large savings are possible by setting a proper routing policy, selecting the most suitable layout along with ABC zoning; all together is making order picking process more effective.

The proposed research could be useful when designing order-picking warehouses and could help the warehouse designer to analyse the efficiency of the selected warehouse layout along with routing policy and ABC zoning in the early stage of project.

For the future work two- or three-block warehouse layout with different notation of ABC zoning, should be analysed.

6. ACKNOWLEDGEMENTS

A part of this research is done within the project TR35006 supported by the Ministry of Education, Science and Technological Development of Republic of Serbia.

7. REFERENCES

[1] De Koster, R., Le-Duc T.; Roodbergen K.J.: *Design and Control of Warehouse Order Picking: a literature review*, European Journal of Operational Research, (2007), 481–501.

[2] De Koster, M.B.M., Vanser Poort E.S., Wolters M.: *Efficient orderbatching methods in warehouses*, International Journal of Production Research 37(7)(1999), 1479–1504.

[3] Dukic, G., Oluic C.: *Order-picking methods: improving order-picking efficiency*, International Journal of Logistics Systems and Management 3(4)(2007), 451–460.

[4] Dukic, G., Oluic C.: *Order-picking Routing Policies: Simple Heuristics, Advanced Heuristics and Optimal Algorithm*, Strojniški vestnik – Journal of Mechanical Engineering 50(11)(2004), 530–535.

[5] Dukic, G., Opetuk T.: *Analysis of order-picking in warehouses with fishbone layout*, Proceedings of ICIL'08, Tel Aviv, Israel, 2008.

[6] Gue, K.R., Meller R.D.: *Aisle Configurations for Unit-Load Warehouses*, IIE Transactions 41(3)(2009), 171–182.

[7] http://www.roodbergen.com/ accessed in May 2016.

[8] Petersen, C.G.: *An evaluation of order picking routeing policies*, International Journal of Operations & Production Management 17(11)(1997), 1098–1111.

[9] Petersen, C.: *The impact of routing and storage policies on warehouse efficiency*, International Journal of Operations & Production Management 19(10)(1999), 1053–1064.

[10] Petersen, C.G., Aase G.: *A comparison of picking, storage and routing policies in manual order picking*, International Journal of Production Economics 92(1)(2004), 11–19.

[11] Roodbergen, K.J., Vis I.F.A.: *A model for warehouse layout*, IIE Transactions 38(10)(2006), 799–811.

[12] Ratliff, H.D., Rosenthal A.S.: *Order-picking in a rectangular warehouse: a solvable case of the travelling salesman problem*, Operations Research 31(3)(1983), 507–521.

[13] Tompkins, J.A., Harmelink D.: *The Supply Chain Handbook*, 2014.

[14] Vaughan, T.S.; Petersen C.G.: *The effect of warehouse cross aisles on order picking efficiency*, International Journal of Production Research 37(4)(1999), 881–897.

METHOD OF EFFECTIVENESS EVALUATION OF PRODUCTS PICKING PROCESS FOR PICK BY ORDER TYPE IN WAREHOUSE ON BASIS OF A PICKING LIST

Augustyn LORENC[1]

[1]Cracow University of Technology, Institute of Rail Vehicles
al. Jana Pawła II 37, Kraków,
Poland

Abstract:

Evaluation of the effectiveness of the orders picking process is most often performed on the basis of indicators such as labour productivity, warehousemen labour intensity, picking performance, correctness of picking and the cost of pallets moving through the warehouse per year. These indicators allow in approximate way to perform the analyse of efficiency for the orders picking process. The original method for evaluating the effectiveness of the order picking process based on the generation of picking lists and simulation of picking process has been presented. This method can be used for comparative analysis aiming to determine which of the considered product placement systems or products classification method used in the warehouse is more efficient due to orders picking time. Presented method allows a much better depict the picking process than the use of the indicators.

Keywords:

warehousing, order picking, pick-by-order, evaluation effectiveness method

1. INTRODUCTION

The warehouse main element of transport system, which join several stages of products movement in transport chain. It is a point, in which many processes related with transportation and transhipment of cargos take place [1,2]. Into that processes could be include: product picking, preparation to delivery, consolidation and others like information flow.

One of the main process taking place in warehouses is products picking [3–6]. It is comprehensive process, because it join correlated elements, like: information flow, transport mode, routing, stocking system and cargos. During that process, actions listed above take place:

- preparation of transport units for picking, aimed to fast and direct access to cargos,
- orders picking, which is manual picking of products specified in picking list,
- verification of quantity, aimed to confirm completeness of transport units with picking list (products type and quantity),
- packing and formation of transport units. Packing is aiming protecting cargos against harmful effects of environment and products effect to environment. Packing also helps to increase control of groupage. Transport units formation helps to increase effectiveness of using transport modes and easily moving, identification and handling,
- moving to dispatch zone and shipment.

Process of picking orders deserve to a special attention due to resources needs and costs, which can be between 37% [7] and 55% [8] of total costs of warehousing. Taking into consideration related process, i.e. packing and loading, it could be even 61% of total costs [1,8]. Categorization of warehouse costs, in Pareto-Lorenz diagram is showed in Figure 1.

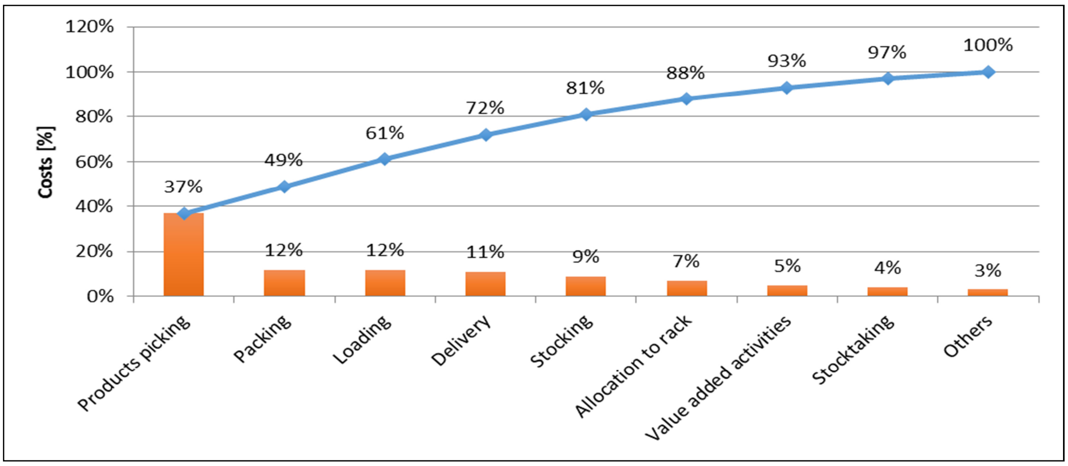


Figure 1 – Categorization of warehouse costs, based on [9,16]

Because of the biggest costs of product picking, the effectiveness of it should be performed. Generally it is possible thanks to indicators, which are presented in the next part of that paper. That indicators does not reflect the whole information about processes of picking, and cannot be used to predict time of picking after changing of product allocation in warehouse. Because of that a mathematical model for orders picking simulation was formulated. This model can imitate a real picking process in warehouse with a high degree of similarity. To do that, method based on simulation of orders picking process instead of classic indicators was used. Based on generated orders picking list, picking route was appointed.

2. THE LIST OF ABBREVIATIONS

$\overline{l_p}$ – the average number of employees in the warehouse, storekeeper,
d_{cr} – the aisle width,
D_{lr} – the rack width,
dr_{poprz} – length of route across the warehouse,
d_{rwzd} – length of route along the warehouse,
D_{wr} – the rack width,
I_c – is correction indicator,
I_p – the intensity work of employees, loading unit /man-hour or kg/man-hour,
K_p – the cost of pallets flow through the warehouse, EUR/quantity,
K_{rm} – the annual cost of storage, EUR,
l_h – the number of hours worked by storekeeper, man-hour,
l_{korwz} – total value of longitudinal aisle, rounded up,
l_p – the number of storekeeper, workers,
l_{reg} – the number of rack in row,
l_{sp} – the number of picked lines in order, quantity,
l_{sp} – the number of items picked, quantity,
l_{spp} – the number of items correctly picked, quantity,
P_k – the correctness of picking,

P_{pmax} – is maximal value,
P_{pmin} – is minimal value,
P_q – product quantity,
P_r – annual flow of units through the warehouse, quantity,
t_a – additional time of penalty for forklift turn,
t_{lp} – time of moving 1 meter straight route,
t_p – time of lifting and lowering folk on specified stock level (p),
t_{pp} – total moving time,
t_{pr} – work time per shift, h,
W_k – the picking productivity, quantity/man-hour,
w_{om} – the turnover of warehouse understood as the sum of delivery and dispatch, quantity or kg,
W_p – the work productivity, loading unit/storekeeper or kg/storekeeper,
x_{konc} – coordinate of destination rack in row,
x_{pocz} – coordinate of actual rack in row,
x_{temp} – route length between coordinates for racks in row,
y_{konc} – coordinate of destination row,
y_{pocz} – coordinate of actual row,
y_{temp} – route length between coordinates for row,

3. STATE OF THE ART

In books, the effectiveness is defined as evaluation of propriety aims realization by system or as adaptation of system to realizations of actions. The effectiveness is main criterion of evaluation on system level, subsystem level or each elements of systems [10].

To evaluation of efficiency and effectiveness of logistics processes, indicators are mainly used. There are calculated manually or by WMS (*Warehouse Management Systems*). This formulas are presented inter alia by S. Krzyżaniak [11].

The work productivity is calculated using the formula (6).

$$W_p = \frac{w_{om}}{l_p} \tag{6}$$

The intensity work of employees is calculated using the formula (7).

$$I_p = \frac{w_{om}}{l_h} \tag{7}$$

The picking productivity is calculated using the formula (8).

$$W_k = \frac{l_{sp}}{l_p \cdot t_{pr}} \tag{8}$$

The correctness of picking is calculated using the formula (9).

$$P_k = \frac{l_{spp}}{l_{sp}} \cdot 100\% \tag{9}$$

In the literature there is no position describing other methods of assessing the effectiveness besides statistical methods and indicators. In practice the only known method based on the indicators.

4. THE METHODS OF ORDERS PICKING

The choice of orders picking method have great impact to effectiveness of internal transport system in warehouse. This choice is strongly correlated with type of picked products, its rotation, number of items in order, time restrictions, etc. In this part of paper, mainly used method are presented.

4.1. Pick by order

Method picking by orders refers to direct picking each lines (item assortment) from order by employee. Picking is realized manually by use picking container (chest, box, basket, etc.) or picking trolley (hand pallet truck, powered pallet truck , counter-balance truck, etc.). That type of picking method is done after last item was putted into a picking trolley – so picking list completion. Employees are moving in warehouse between rack order defined by picking list, RF terminal or given by voice picking system. The sequence of products picking is determined manually or automatic by WMS [12].

The advantage of that method is orders picking in real time so, there is no needs to sort product to orders before dispatch. What is more, risk of mistake while moving products between orders.

Picking by order is one of the most common methods. However for medium size or big warehouse (over 5 000 m^2), it is necessary to move on large distance between products stocked in warehouse, so needs to humans work increase. This increases the cost of warehouse and exploitation of transport modes.

4.2. Cluster picking

Picking a few orders in the same time – also called multi picking or cluster picking deals with picking two or more orders in simultaneously. In the same time products are sorted to orders. That method is used in case when it is able to separate each orders in picking trolley.

The number of orders, which can be picked basis on this method, depends on numbers of lines and items of products on picking list. It is also depends on volume, weight and picking trolley capacity.

4.3. Batch picking

Batch picking its similar method to cluster picking. Main difference between these is that in batch picking, the same products from each orders are joined together in one picking order. After picking from rack product are putted into one trolley without separate into orders. Dividing product into orders is different process independent of picking products in stocking zone.

In batch picking, two methods of product picking can be defined [9]:

- **pick by line**, each products quantity is rounded to full loading unit. After dividing into orders, unused products are returned to stock zone or if it is possible assigned to new orders.
- **pick to zero/ bulk picking**, each products quantity is picked in exact number as given in the order. The process continues until each products are picked.

The route shorten and high level of faultless are main advantages of those type of picking. What is more it increase efficiency – higher indicator of line picking per hour.

4.4. Pick and Pass/Zone picking

The zone picking also called pick and pass base on dividing stocking zones into smaller one. The size of those zones are related with products rotary – the bigger rotary indicator the smaller stocking zone. Each stocking zones are supported by one workers. The employees are picking product only in their zones.

The order is passing through zones until whole products in order is picked [2].

The orders can be picked simultaneously within the zones and consolidated later or they can be picked sequentially. Separate pick instructions are produced by the WMS for each zone for simultaneous picking. A single pick list travels with each order for sequential picking.

The volume of orders sent to each zone needs to be controlled so that each factor has an equivalent amount of picks. The potential for bottleneck can be high with staff having to wait for orders to arrive [9].

4.5. Wave picking

In wave picking, orders are combined and released at specific times during the day or to associate them with vehicle departures, replenishment cycles, shift changes, product locations, product commonality, value-adding service requirements and priorities. The use of wave picking can also balance workload by time or by area by logically grouping and releasing orders.

Orders can be released at different times to different zones based on how long it takes to pick the orders. The drawback is the requirement for a further step in the process, having to bring the partial orders back together. However, as discussed with batch and zone picking, it does allow for a second check on product codes and quantities [14].

5. METHOD OF EFETIVENESS EVALUATION OF ORDERS PICKING

The effectiveness evaluation of processes in warehouse can be made by a few criterion, i.e. time of orders picking, route length, chattiness (employees works, costs, transport modes). In this paper, as criterion of effectiveness evaluation, time of orders picking has been established. Base on it, the methods which helps to reduce picking time were chosen.

To evaluate effectiveness of orders picking process in cases of allocation product based on product classification method, mathematical model was formulated. This model can imitate a real picking process in warehouse with a high degree of similarity. To do that, method based on simulation of orders picking process instead of classic indicators was used.

Based on generated orders picking list, picking route was appointed. Most of small and medium size warehouses use planning order of picking product by nearest product stocked in rack from actual position of worker [15]. For that cases algorithm showed in Figure 2 was designed.

The functioning of that algorithm can be presented in few steps.

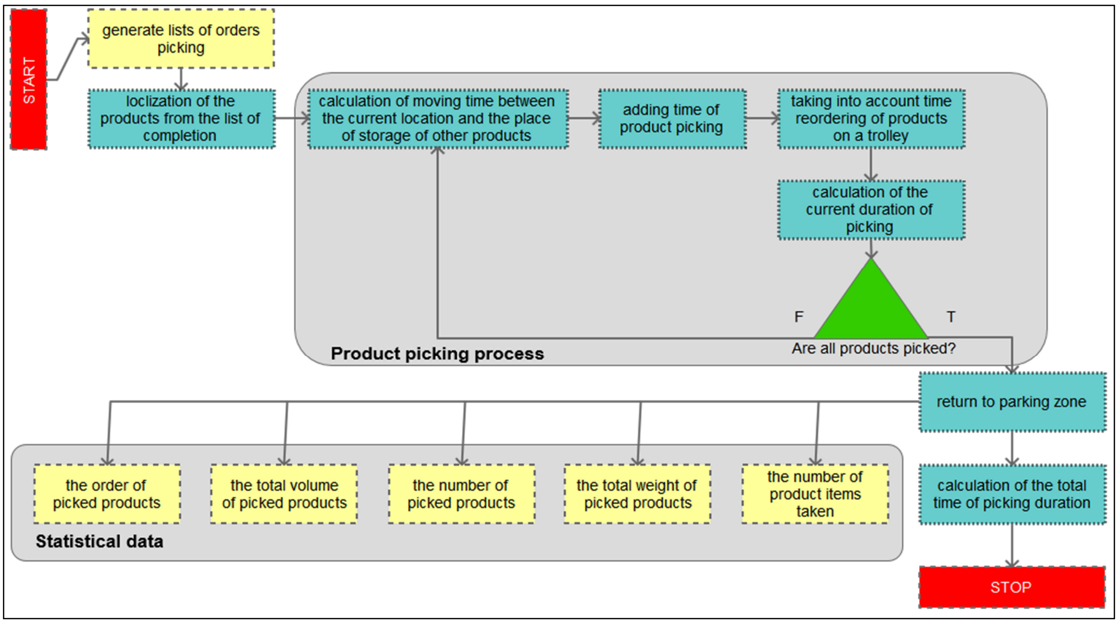


Figure 2 – The block diagram of algorithm of products picking effectiveness evaluation

First of all, product ID is randomly chosen from whole available IDs in group. Afterwards the nearest location of that product stocked is chosen. As nearest product is understood product characterized by shortest time of moving from actual location (start point in packing zone id marked as point (0, 0, 0)). In that case mentioned time is read from access time matrix, generated in warehouse structure planning process. The coordinates of destination point are described by three variables x_{do} *(rack)*, y_{do}*(row)*, p_{do}*(level)*. The time of moving from one point to another are added to total order picking time. Next, product quantity are draw from the scope. Wherein that quantity is correlated by correction indicator with total number of product sold. It can be described by PHP formula (10).

$$P_q = ceil(rand(P_{p\min} \cdot \$ratio \cdot 100,\ P_{p\max} \cdot I_c \cdot 100)) \qquad (10)$$

where:
ceil – is PHP function rounding decimals up to the value of total,
rand – is PHP function drawing values from the scope (min, max),

In next step, another product ID is draw. In this case, access time is not read from access time matrix. The moving time between actual and next product is calculated for each steps. It is not possible to calculate that time for each possibilities, because of matrix size. In that case it will be necessary to generate the same quantity of matrix as quantity of stocking place in warehouse. What is more each matrix will have the same size – equal to number of stocking place. For 40 rack (3 palette unit in one rack level), 10 row and 3 stock level, there will be 1200 matrix and each of them will have a size of 120x30. So that solution will be not effective.

The algorithm for calculation moving and products picking time, could be presented in steps presented above.

Step 1 – In first step the absolute value of coordinates subtraction between actual and destination point is calculated (11). The *x* value is number of racks in row, and *y* value is number of rows.

$$x_{temp} = \left| x_{pocz} - x_{konc} \right|$$
$$y_{temp} = \left| y_{pocz} - y_{konc} \right| \tag{11}$$

Step 2 – In second step, it is check that both racks are located in the same row and if that row is coming out of packing zone – start point. That condition is formulated as (12).

$$x_{temp} \neq 0 \;\; and \;\; x_{temp} \neq 2 \tag{12}$$

Step 3 – If condition presented in step 3 is has been met, two turns must be included in the time calculation $l_{luk} = 2$. What is more, if rack are located in two rows, so for each product stocked access is available, additional longitudinal aisles must be take into account. The number of that aisle can be calculated by formula (13).

$$l_{korwz} = \frac{y_{temp}}{3} \tag{13}$$

In that case length of route across the warehouse described the formula (14).

$$dr_{poprz} = D_{wr}(y_{temp} - l_{korwz}) + d_{cr} \cdot l_{korwz} \tag{14}$$

Step 4 – If in analysed warehouse is one transverse aisle, must be checked that both of actual and destination rack are in the same or different warehouse zone. It can be done by formula (15).

$$\left(x_{pocz} \leq \frac{l_{reg}}{2} \;\; and \;\; x_{konc} > \frac{l_{reg}}{2} \right) \; or \; \left(x_{konc} \leq \frac{l_{reg}}{2} \;\; and \;\; x_{pocz} > \frac{l_{reg}}{2} \right) \tag{15}$$

Step 5 – If condition in step 4 is fulfilled, route along warehouse (d_{rwzd}) can be calculated by formula (16).

$$dr_{wzd} = D_{lr} \cdot d_{cr} \left(\left| x_{pocz} - x_{konc} \right| - 1 \right) \tag{16}$$

Step 6 – If condition in step 4 is not fulfilled, must be checked in which zone of warehouse (before or after the transverse aisle) are both racks (17).

$$x_{pocz} < \frac{l_{reg}}{2} \tag{17}$$

Step 7 – If condition in step 6 is fulfilled, both of rack are in first (nearest) warehouse zone, so if:

$$D_{lr} \cdot d_{cr}(x_{pocz} + x_{konc}) < D_{lr} \cdot d_{cr}(l_{reg} - x_{pocz} - x_{konc}) \tag{18}$$

that:

$$dr_{wzd} = D_{lr} \cdot d_{cr}(x_{pocz} + x_{konc}) \tag{19}$$

else:

$$dr_{wzd} = D_{lr} \cdot d_{cr}(l_{reg} - x_{pocz} - x_{konc}) \tag{20}$$

Step 8 – If condition in step 6 is not fulfilled, both of rack are in second warehouse zone, so if:

$$D_{lr} \cdot d_{cr}(x_{pocz} + x_{konc} - l_{reg}) < D_{lr} \cdot d_{cr}(2l_{reg} - x_{pocz} - x_{konc}) \tag{21}$$

that:

$$dr_{wzd} = D_{lr} \cdot d_{cr}(x_{pocz} + x_{konc} - l_{reg}) \tag{22}$$

else:

$$dr_{wzd} = D_{lr} \cdot d_{cr}(2l_{reg} - x_{pocz} - x_{konc}) \tag{23}$$

Step 9 – If condition in step 2 is not fulfilled, in calculation there is no needs to add turns, so $l_{luk}=0$. Also route length in transverse aisle is equal to zero ($dr_{poprz}=0$). So length of route in longitudinal aisle is depended on that, both of racks are in the same zone or not. So if formula (24) is fulfilled:

$$\left(x_{pocz} \le \frac{l_{reg}}{2} \;\; and \;\; x_{konc} > \frac{l_{reg}}{2}\right) \; or \; \left(x_{konc} \le \frac{l_{reg}}{2} \;\; and \;\; x_{pocz} > \frac{l_{reg}}{2}\right) \tag{24}$$

both racks are in different zones, so:

$$dr_{wzd} = D_{lr} \cdot d_{cr}(x_{konc} - 1) \tag{25}$$

else:

$$dr_{wzd} = D_{lr} \cdot x_{konc} \tag{26}$$

Step 10 – Based on calculated picking route, time of moving duration must be calculated (27).

$$t_{pp} = t_{lp}(dr_{wzd} + dr_{poprz}) + t_a \cdot l_{luk} + t_p \tag{27}$$

Except calculation of order picking time, designed algorithm allow to obtain information about order of product picked and statistical information about order, like: total product volume and weight, picked products quantities and picked lines in order.

6. CASE STUDY

To evaluate the effectiveness of the completion process derived from the applied method of product distribution in the warehouse one should use a model which allows precise representation of processes occurring in the real warehouse. Hence, a special method has been used. The method shows clients' orders which undergo the completion process in warehouses, i.e. the method uses random lists of product completion. On the basis of the generated completion lists, the route of product completion was determined with the use of a method applied by the majority of medium size enterprises which have their own warehouses. The method determines the completion routes by relying on the closest point with reference to the current localization of the warehouseman. The method also concerns the need of interference in the arrangement of products on the completion trolley if there is a risk of crushing a smaller product by a bigger one, i.e. sensitivity to stacking.

For simulations, algorithms created by the authors were used. The algorithms constitute the basic software written in the PHP language. They use relation mySQL databases. Thanks to this solution it is possible to use great data sets, to present the results in a clear way, and to easily modify the input parameters. Moreover, this solution enables the integration of the basic software with the Matlab software.

The simulations were conducted on the basis of the 1000 generated lists of the completion of products characterized by the following parameters:

- weight: from 0.1 to 6 kg,
- volume: from 0.1 to 0.4 m^3,

- the number of product types on the completion list: from 3 to 20 items,
- the number of items of the certain product: from 1 to 60 items.

Simulation was created for a big warehouse with 200 spots for pallet units in each of 14 product storage rows and 6 storage levels. In the simulation, 1000 various products were used. The completion lists for the products were prepared according to the established assumptions. Figure 3 presents the result of the simulation of the product completion time in a graphical form.

Figure 4 allows one to notice that methods such as the ABC and XYZ analyses, the method of free product storage places, the ABC analysis according to the criteria of popularity and number of sold items, and the ABC analysis together with the COI Index according to the criteria of popularity and weight yield the results of the greatest range and standard deviation. It is also noticeable in the descriptive statistics presented in Table 1.

The variance analysis (ANOVA) was conducted for the performed analyses in order to test the significance of differences between average values. The ANOVA analysis performs a distribution of data variances into two components: the component between groups and the component within the group. The index of Test F, which equals 148.23 in this case, is a ratio of evaluation between groups to the evaluation within the group. Since the value of the index p for Test F is lower than 0.05 then, with 95% of confidence level, there is a statistically significant difference between the averages from the conducted analyses.

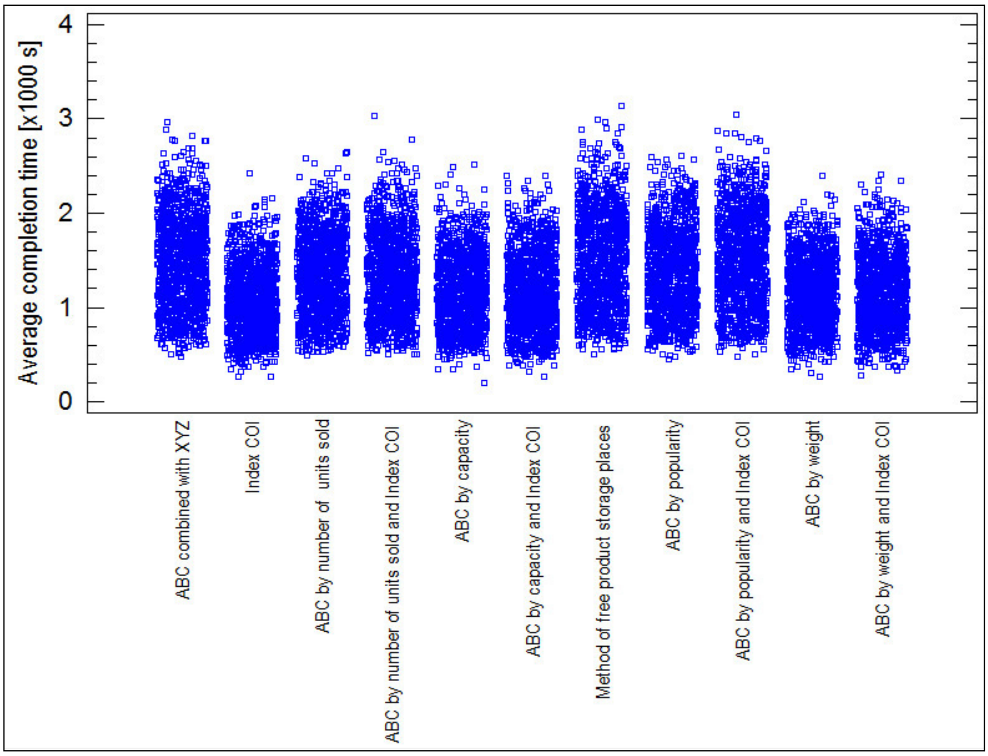


Figure 3 – Product completion time depending on the applied method of product classification

Table 1 – Descriptive statistics of the analyses performed [s]

	Average	Standard deviation	Median	Min	Max	Range
ABC combined with XYZ	1488	490	1479	470	2961	2491
Index COI	1092	367	1072	269	2422	2153
ABC by number of units sold	1348	432	1344	491	2646	2155
ABC by number of units sold and Index COI	1367	449	1357	499	3028	2529
ABC by capacity	1179	390	1141	205	2512	2306
ABC by capacity and Index COI	1180	412	1139	268	2401	2133
Method of free product storage places	1532	510	1518	508	3141	2633
ABC by popularity	1387	453	1392	444	2610	2166
ABC by popularity and Index COI	1509	507	1508	473	3042	2569
ABC by weight	1162	367	1155	262	2399	2137
ABC by weight and Index COI	1162	394	1154	275	2409	2134
Total	1310	462	1271	205	3141	2936

To state which groups statistically differ one from another, multiple comparisons, the so-called *test post hoc*, were made. To carry out multiple comparisons we use: Scheffe's test, Tukey's (HSD) test, Fisher's (LSD) test, Bonferroni's test, Newman-Keuls test and Duncan's test. In the analyzed case, the Scheffe's test was carried out. This test is considered as one of the most conservative "careful" post hoc tests [16]. The result of the test is shown in Figure 4.

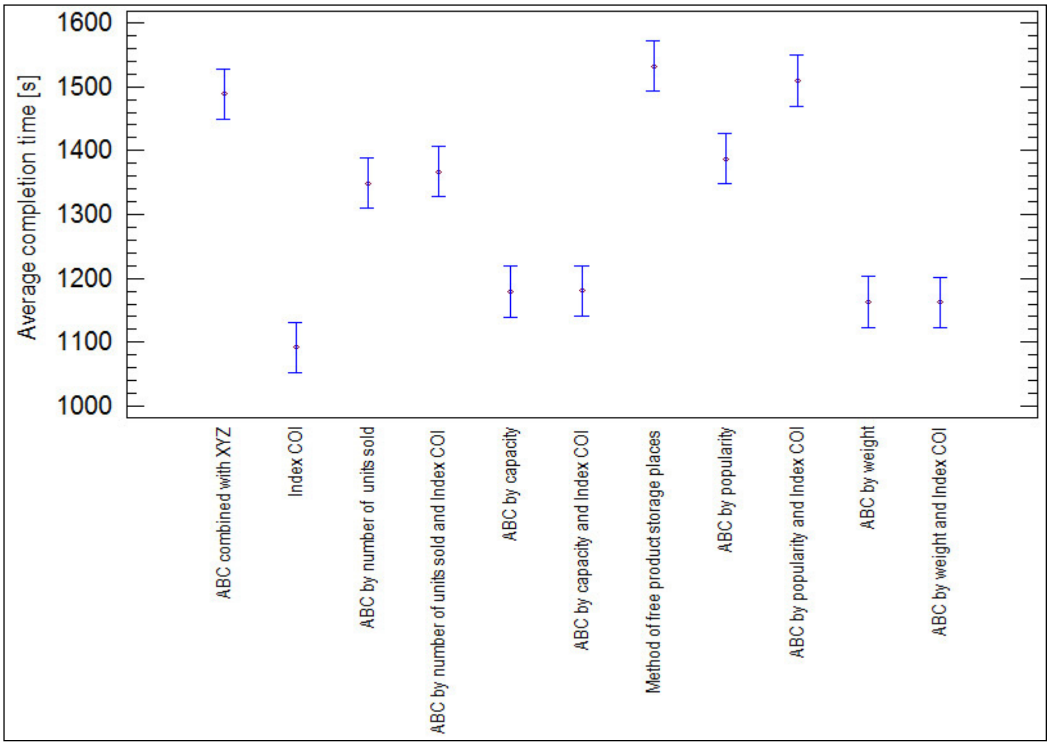


Figure 4 – The result of comparison of averages with the Scheffe's interval with 95% of confidence level

Comparison of the medians with the use of the Friedman test was the last part of the analysis. The null hypothesis assumed that all the attempts came from the population of the same median [16]. The result of the test was 3727, where the p parameter equaled 0.0. It allowed the statement that the groups significantly differ one from another.

By comparing the average values and medians it was stated that the best result was obtained when the products in the warehouse were distributed on the basis of the COI Index (the average: 1092, the median: 1072). Other methods allowed the following results: the ABC analysis according to the weight criterion (average: 1162, median: 1155), the ABC analysis according to the weight criterion combined with COI (average: 1162, median: 1154), the ABC analysis according to the volume criterion (average: 1179, median: 1141), the ABC analysis according to the volume criterion combined with COI (average: 1180, median: 1139). The methods show a statistical similarity and yield slightly worse results.

The ABC analysis combined with XYZ, the ABC analysis combined with the Index COI according to the popularity criterion and the method of free product storage places give the worst results characterized by their great divergence and high average and median. Thus, for big warehouses it is important to distribute products on the basis of the ABC analysis according to the criteria of weight, volume and COI index. This method allows for obtaining better results than in the case of free storage places by 28.72% on the average.

7. CONCLUSIONS

Designed algorithm of orders picking time calculation for Pick by order, can be used to simulate picking processes in warehouse. So calculation of time by those method better describe real picking process that classic indicators. That algorithm can be used to impartial evaluation of effectiveness, and can be used for comparing different variants of product allocation in warehouse. The simulation can be done for any data describing warehouse structure, any product types and number of picking process. Thereby statistical analysis of picking process can be done. Results of many simulation can increase certainty of describing real picking process which classic methods cannot ensure.

Based on that method the simulations of orders picking were performed. Simulation was created for a big warehouse with 200 spots for pallet units in each of 14 product storage rows and 6 storage levels. In the simulation, 1000 various products were used. For average-size and large-size warehouses it is important to distribute products on the basis of COI Index. This method allows to obtain better results than in the case of free storage places by an average of 28.72%.

In the future works is planned to use presented method of effectiveness analysis for others simulations. The planned simulations will helps to define: correlation of product classification method with size of warehouse, impact of level of warehouse automation to effectiveness, and others. So presented method will be the base for future research.

8. REFERENCES

[1] Gajewska, T., Zimon D., Malindzak D.: *Wpływ systemu zarządzania jakością na doskonalenie procesów magazynowych*, Logistyka 3(2015), 5102–5108.

[2] Lorenc, A., Szkoda M.: *Zastosowanie systemu SAP ERP do obsługi dostaw Just-in-Time oraz Just-in-Sequence w branży motoryzacyjnej*, Logistyka 3 (2015), 2877–2886.

[3] Kłodawski, M, Jacyna M.: *Wybrane aspekty problematyki komisjonowania w funkcji pracochłonności procesu*, Logistyka 4 (2009).

[4] Kłodawski, M., Jacyna M.: *Wpływ układu strefy komisjonowania na długość drogi kompletowania*, Logistyka 4 (2010).

[5] Kłodawski, M., Jacyna M.: *Czas procesu kompletacji jako kryterium kształtowania strefy komisjonowania*, Logistyka 4 (2011).

[6] Jacyna, M., Kłodawski M.: *Pracochłonność procesu komisjonowania dla wariantowego rozmieszczania asortymentu w strefie kompletacji*, Prace Naukowe PW. Transport 70, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2009.

[7] Guvenir, H.A., Erel E.: *Multicriteria inventory classification using a genetic algorithm*, European Journal of Operational Research 105(1)(1998), 29–37.

[8] Accorsi, R., Manzini R., Maranesi F.: *A decision-support system for the design and management of warehousing systems*, Computers in Industry 65(1)(2014), 175–186.

[9] Gwynne, R.: *Warehouse management – 2nd edition, a comlete guide to improving efficiency and minimizing costs in the modern warehouse*, Kogan Page, London 2014.

[10] Jacyna-Gołda, I.: *Wskaźniki oceny efektywności funkcjonowania obiektów magazynowych w łańcuchach dostaw*, Prace Naukowe Politechniki Warszawskiej (105)2015.

[11] Krzyżaniak, S., Niemczyk A., Majewski J., Andrzejczyk P.: *Organizacja i monitorowanie procesów magazynowych*, Instytut Logistyki i Magazynowania, Poznań 2014.

[12] Boysen, N., Stephan K.: *The deterministic product location problem under a pick-by-order policy*, Discrete Applied Mathematics 161(18)(2013), 2862–2875.

[13] Rushton, A., Croucher P., Baker P.: *The handbook of logistics and distribution management. Understanding the supply chain*, Kogan Page, London 2014

[14] Vitasek, K.: *Supply chain management terms and glossary*, Scvisions 2013.

[15] Pan, JCH., Wu MH., Chang WL.: *A travel time estimation model for a high-level picker-to-part system with class-based storage policies*, European Journal of Operational Research 237(3)(2014), 1054–1066.

[16] Pan, JCH., Shih PH., Wu MH.: *Order batching in a pick-and-pass warehousing system with group genetic algorithm*, Omega-International Journal Of Management Science, Part: B 57(2015), 238–248.

IMPACT OF A JUST-IN-SEQUENCE SYSTEM ON THE EFFECTIVENESS OF INTERNAL TRANSPORT IN AUTOMOTIVE INDUSTRY

Augustyn LORENC[1], Maciej SZKODA[1]

[1]Cracow University of Technology, Institute of Rail Vehicles
Jana Pawla II Str. 37, Krakow,
Poland

Abstract

Just-in-Time (JiT) system, used by most manufacturing companies, is being increasingly replaced by more efficient Just-in-Sequence (JiS) system. The latter one allows direct delivery of products to the production line without the warehouse storage process. In this paper the impact of JiS application on the effectiveness of internal transport system in a manufacturing company (automotive industry) is examined. Two mathematical models (for JiT and JiS) have been developed to map the manner and duration of the processes of components' transportation to the production line. For both systems the effectiveness analysis was made to determine the benefits of using the Just-in-Sequence system: the economy of time, manpower, means of transport and storage space.

Keywords:

Just-in-Time, Just-in-Sequence, internal transport, automotive industry, effectiveness

1. INTRODUCTION

In Poland, there are more than 660 manufacturers of automotive parts and 350 of them hold top-quality certificates such as ISO/TS 16949. They manufacture parts for all automobile makes. As many as 9 out of 10 leading world manufacturers of parts have their manufacturing plants in Poland. Major operators in the Polish market include Bosch, Brembo, Delphi, Gates, Johnson Controls, Mahle, Tenneco Automotive, ThyssenKrupp Automotive, TRW Automotive, and Valeo. According to a report by the Polish Association of Automotive Parts Distributors and Manufacturers (SDCM), 20% of the parts used for assembling automobiles come directly from automotive companies whilst 80% of them are supplied by independent manufacturers who sell products under their own brands [1]. The system for the distribution of finished products depends on the requirements set by end-customers. Due to the specificity and continuity of operation of manufacturing lines, the manufacturing industry and the automotive industry in particular, set the highest requirements for their suppliers. These apply not only to the high quality of sub-assemblies but the organisation of supplies themselves and delivery of products within specific time windows. For the purposes of delivery processing, manufacturers of automotive parts divide their customers into specific groups, for instance [2–5]:

- OEMs (Original Equipment Manufacturers);
- OESs (Original Equipment Services); and
- AAMs (Automotive Aftermarket).

The division of customers into groups is very important due to the timeliness of deliveries and the consequences of the failure to meet their terms and conditions. Parts delivered to OEM customers are the ones to get into serial production. In order to optimise operations, most manufacturers reduce their inventories to zero thus eliminating the loss of capital frozen in the stock. The parts delivered to them get straight into production following the JiT (Just in Time) and JiS (Just in Sequence) rules. Because of that, non-delivery of a part on time may cause stoppage of the manufacturing line thus exposing the supplier to huge costs. Hence, customer logistic services provided to OEMs require high precision and long-term production planning. The parts for such customers are manufactured as first priority. The delivery schedules are provided one year in advance in order to plan the Master Production Schedule. The nature of the OEM customer group requires that methods are set to ensure timely deliveries, which is discussed further in the paper. What is most important to this group of customers is the timeliness and flexibility of deliveries. The volume of each order, apart from the order freezing period, may change within a certain percentage range. The customer requires the option of having the product delivered in bigger or smaller quantities. Flexibility is also understood as the possibility of moving the time of delivery backward or forward, as required by the customer. The OEM customer group requires continued contact to be kept and information to be provided about any problems or complications.

The second group is OES customers for whom parts are delivered to authorised service points of automotive manufacturers. OES parts as the same as the ones for the OEMs but with different reference names in order to follow the safety requirements and distinguish between production priorities. For most projects, OEM and OES parts are shipped at the same time but to different destinations. After the termination of the contract for supplies for the assembly line, the manufacturer of subassemblies is obliged to continue production for a certain period of time or keep a certain stock level with the OES customer. The primary characteristic with respect to this customer group is the capability of processing orders which change frequently following changeable demand. Timeliness of deliveries is a secondary issue. For many customers, the acceptable time of delivery is within the tolerance range of two days from the required delivery date. This also relates to optimisation of the loading space in means of transport. The other aspect is the completeness of deliveries – the customer requires delivery of all ordered parts. A long shortage of a particular range of products may prevent the customer from providing due service or considerably delay the same.

The third group are AAM customers who offer distribution of spare parts in the market to individual customers. For this group, timeliness is the most important factor in logistic services.

The article presents a comparative analysis of Just in Time and Just in Sequence systems of components delivery, depending on the type of parts, as direct delivery combined with JiT system. Direct delivery to the assembly line, i.e. with no storage in the main warehouse (JiS) is also considered. To evaluate the effectiveness of JiT and JiS systems a comparative analysis of variants is employed.

2. PRODUCTION PROCESS

Assembly lines are process-oriented and are arranged according to the sequence of operations needed to manufacture a product. This is in contrast to job shops which are job-oriented and machines which perform similar operations are spatially grouped together [6].

Automobile manufacture cycle can be divided into stages within which a series of jobs is performed in a sequence. An assembly line with tasks assigned to each workstation significantly accelerates the manufacture, reduces the risk of errors and reduces the skills requirements of workers who need to be skilled only in the tasks required for a particular workstation [7]. The car production cycle can be divided into the following stages:

1. Preparation of car body
2. Disassembly of doors
3. Fitting doors with glass, locks, door panels, etc. (performed at a separate workstation)
4. Assembly of groups of electric wires
5. Assembly of floor carpeting, roof lining, seat belts
6. Assembly of gear box wrapping connector
7. Assembly of windows, front and tail lights, and indicator lights
8. Assembly of pillars covers, trunk carpeting
9. Assembly of interior area with dashboard and pedals

9B. Subassembly of interior area module (manufactured at a separate stand)

10. Assembly of engine and exhaust system

10B. Subassembly of the module of engine and exhaust system (manufactured as a separate stand)

11. Assembly of suspension system

11B. Subassembly of suspension system (manufactured at a separate stand)

12. Assembly of bumpers
13. Connecting wire groups to power source
14. Assembly of wheels
15. Assembly of seats
16. Assembly of steering wheel and air bag
17. Fuelling and filling with operating fluids
18. Firmware installation
19. Verification of vehicle parameters
20. Assembly of doors
21. Wheel geometry setting and lights adjustment
22. Inspection of braking system
23. Inspection of tightness

To ensure the continuity of production it is essential to ensure the delivery of required parts to each workstation. Any delay in parts timely supply may cause stoppage at a workstation, which results in the stoppage of the entire production line. This makes it absolutely fundamental to eliminate any delays [8]. Moreover, automotive manufacturing companies aim at limiting their inventory level to reduce the storage space and the capital frozen in the stock. Therefore, what is most important is that orders be delivered more frequently, with no need of keeping the parts in storage over long periods. Parts are delivered to manufacturing plants in Just-in-Time and Just-in-Sequence systems [9].

3. COMPARATIVE ANALYSIS OF JIT AND JIS SYSTEMS

The system of internal transport in manufacturing plants with an assembly line is of particular significance because an error in this area may result in the stoppage of production line. Therefore continuous control of supplying the workstations is required. For each workstation the principle of inventory reduction is followed, at a workstation there should be only the parts that are necessary to perform the assembly jobs in one cycle, at the end of which the workstation should be supplied with components necessary for the subsequent cycle. Consequently, it is necessary to maintain an order and cleanliness of a workplace as well as continuous control of the production process. To achieve this aim the principle of 5S and Kanban card are employed [10].

Components can be delivered to assembly stations as direct delivery or in-time systems performed by logistic trains.

In direct delivery system only one workplace is supplied by a single event of collecting parts from the warehouse and transporting them. This system is most common in the case of large components, no production synchronization between a given workplace and other stations or emergency cases (e.g. lack of parts at the workplace due to incorrect previous delivery, defects of parts etc.).

In-time systems performed by logistic trains are much more efficient. They help reduce the total distance of parts transportation, the number of transportation means moving within a manufacturing plant. All this results in cost reduction by reducing the workforce, transportation means and services. The logistic train is a truck composed of modules that can be uncoupled. The modules are made up of containers loaded with parts and as the truck moves on, they are dropped at the workplaces while the empty containers are picked up to be reloaded. An example of a logistic train is shown in Figure 1.

Figure 1 – Logistic train transporting parts to assembly workstations

In the article components delivery systems performed depending on the type of parts in direct delivery systems combined with in-time systems (JiT) are discussed. Delivery directly to the assembly line, i.e. with no storage in the main warehouse (JiS system) is also analysed. To evaluate the efficiency and effectiveness of JiT and JiS systems a comparative analysis of two variants has been made.

3.1. Variant I – JiT

In variant I only the employment of JiT delivery to a company is considered. All the components are stored in one warehouse. They are distributed to particular workplaces by direct and in-time deliveries. The warehouse must have a considerable storage space and a stock of parts. A scheme of the production line is shown in Figure 2.

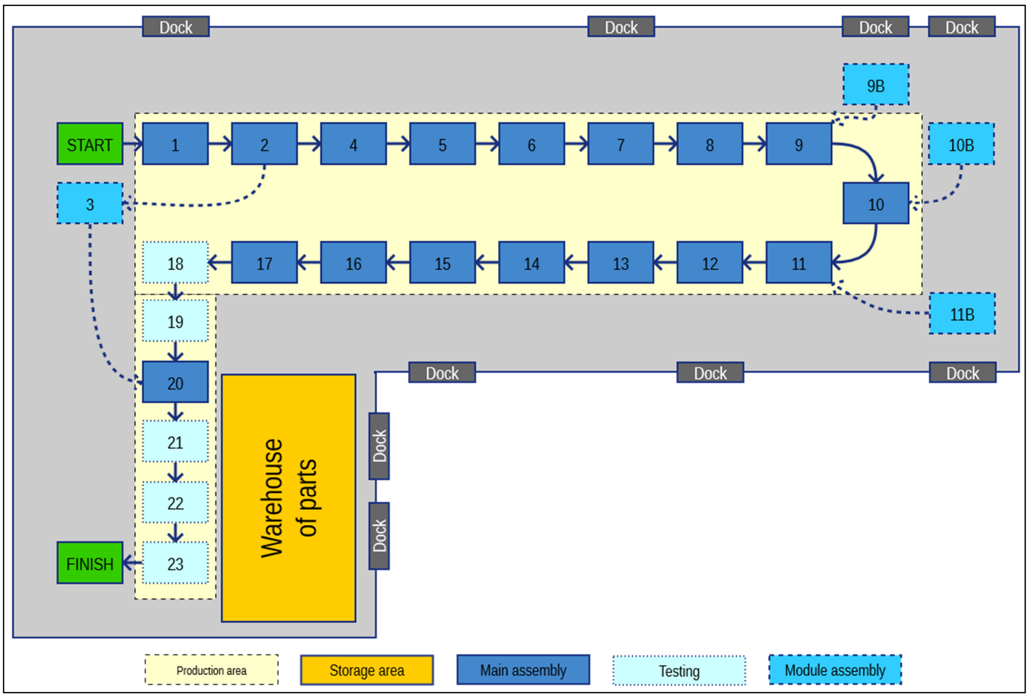


Figure 2 – Production line with JiT components delivery; numbers of processes as in subsection 2

For the arrangement of the production line shown above the workplaces were divided according to the demand for direct or in-time deliveries.

For supplies which are realized in JiT system, the mathematical model was developed. This model enables to determine time of parts supplies to all assembly station during one full production cycle. This model is described by formula (1).

$$T_t = \sum_{n=1}^{m}\left(\sum_{i=1}^{j}\left(d(i-1,i)\cdot v_m + t_m(i)\right) + d(j,s)\right) \tag{1}$$

where:

T_t – the time of supplies all parts in one full production cycle, s,
n – the logistic train,
m – the number of all logistic train supplying the parts,
$d(i-1, i)$ – the distance between previous and actual station, m,
$d(j,s)$ – the distance between last station and warehouse, m,
v_m – the average speed of logistic train in one meter straight line, m/s,
i – the assembly station supplied by logistic train,
j – the number of assembly stations,
$t_m(i)$ – the time of operational activities at i-assembly station, s.

In analyzed example in both models the time of loading parts into logistic train bins or forklifts (for direct supplies in buffer warehouses in JiS system) is the same. Because of that and that the aim of simulation was to compare effectiveness of both systems (variant I and variant II) the mentioned times of loading were omitted in both developed models.

Based on the above mathematical model simulations were performed, the results of which are presented in the table 1.

This division together with delivery time of all the components required for a given workplace is shown in Table 1.

Table 1 – Type of components delivery for a given stage and delivery time for variant I [s]

Stage	Jobs	Direct delivery	Logistic train	Total
1	Preparation of car body	79	x	79
2	Disassembly of doors	13	x	13
3	Fitting doors with windows, locks, door panels, etc. (separate workstation)	x	40	40
4	Assembly of groups of electric wires	x	28	28
5	Assembly of floor carpeting, roof lining, seat belts	x	6	6
6	Assembly of gearbox wrapping connector	x	6	6
7	Assembly of windows, front and tail lights and direction indicator lamps	x	6	6
8	Assembly of pillars covers, trunk carpeting	x	6	6
9	Assembly of interior area with dashboard and pedals (as a ready-made element)	x	6	6
9B	Subassembly of interior module	x	65	65
10	Assembly of engine and exhaust system (as ready-made element)	13	x	13
10B	Subassembly of engine and exhaust system module	x	12	12
11	Assembly of suspension (as ready-made element)	13	x	13
11B	Subassembly of suspension module	x	60	60
12	Assembly of bumpers	x	97	97
14	Assembly of wheels	x	12	12
15	Assembly of seats	x	6	6
16	Assembly of steering wheel with air bag	x	6	6
17	Fuelling and filling with operating fluids	x	12	12
20	Assembly of doors	21	x	21
	TOTAL [s]	**139**	**368**	**507**

The table does not include components loading/unloading time because this time is the same in both variants and does not affect the result of the comparative analysis. In the "Logistic train" column the two delivery types are marked with different colours.

3.2. Variant II – JiT and JiS

In variant II the possibility of combining two systems of components delivery, i.e. JiT and JiS is analysed. In this variant it is necessary to use buffer warehouses for the storage of components specified for a given workplace. The parts from the buffers are delivered directly to the assembly line, which enables the reduction of transportation distance and the volume of stock. The main warehouse is used for the storage of parts of relatively low value and high demand on the production line. Such parts include, for instance, screws, pads, gaskets and seals, operating fluids. They are delivered as in variant I, i.e. in direct and in-time delivery systems. A scheme of a production line with indicated buffer warehouses is shown in Figure 3.

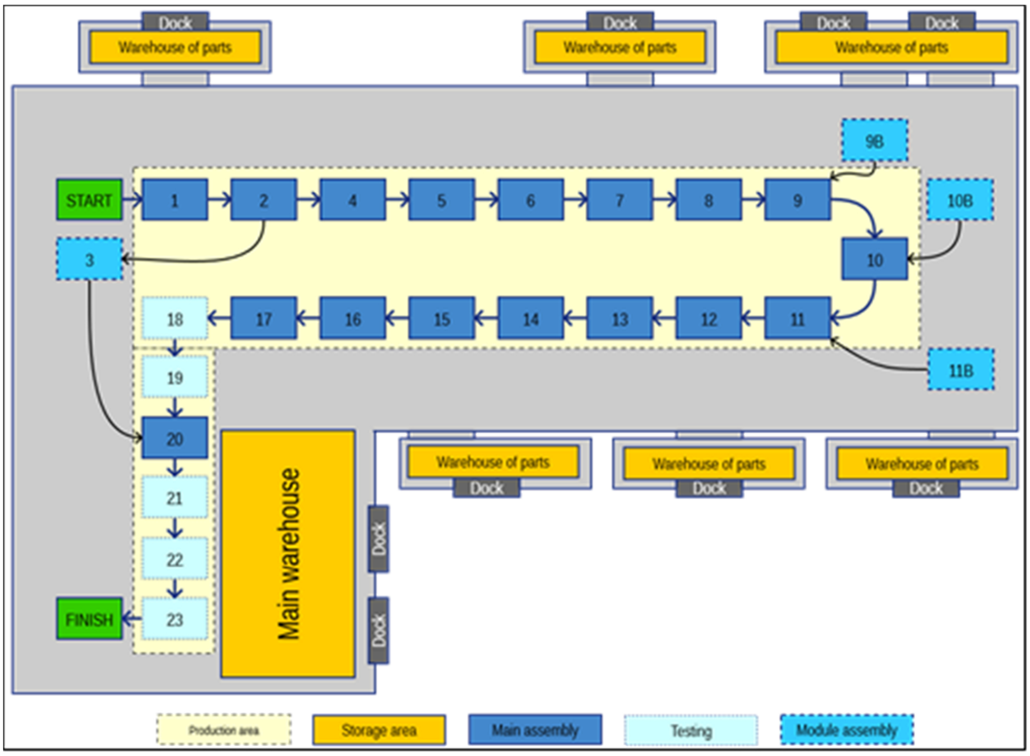


Figure 3 – Production line with JiT and JiS components delivery systems; numbers of process as in Subsection 2

For the system above – like in variant I – the workplaces are divided according to the demand for direct or in-time deliveries.

For supplies which are realized in JiT mixed with JiS system, the mathematical model was developed. This model enables to determine time of parts supplies to all assembly station during one full production cycle. This model is described by formula (2).

$$T_t = \sum_{n=1}^{m} \left(\sum_{i=1}^{j} \left(d(i-1,i) \cdot v_m + t_m(i) \right) + d(j,s) + \sum_{k=1}^{l} \left(2d(k) \cdot v_m + t_m(k) \right) \right) \quad (2)$$

where:
T_t – the time of supplies all parts in one full production cycle, s,
n – the logistic train/forklift,
m – the number of all logistic train/forklifts supplying the parts,
d(i-1, i) – the distance between previous and actual station, m,
d(j,s) – the distance between last station and warehouse, m,
v_m – the average speed of logistic train in one meter straight line, m/s,
I – the assembly station supplied by logistic train in JiT system,
j – the number of assembly stations in JiT system,
k – the assembly station supplied by forklifts in JiS system,

l – the number of assembly stations in JiS system,
$t_m(i)/\, t_m(k)$ – the time of operational activities at i/k-assembly station, s.

Based on the above mathematical model simulations were performed, the results of which are presented in the table 2.

This division together with delivery time of all the components required for a given workplace is shown in Table 2.

Table 2 – Type of components delivery for a given stage and delivery time for variant II [s]

Stage	Jobs	Direct delivery	Logistic train	Delivery from warehouse buffer	Total
1	Preparation of car body	x	x	9	9
2	Disassembly of doors	13	x	x	13
3	Fitting doors with windows, locks, door panels, etc. (separate workstation)	x	40	x	40
4	Assembly of groups of electric wires	x	28	x	28
5	Assembly of floor carpeting, roof lining, seat belts	x	6	x	6
6	Assembly of gearbox wrapping connector	x	6	x	6
7	Assembly of windows, front and tail lights and direction indicator lamps	x	x	9	9
8	Assembly of pillars covers, trunk carpeting	x	12	x	12
9	Assembly of interior area with dashboard and pedals (as a ready-made element)	x	6	x	6
9B	Subassembly of interior module	x	x	4	4
10	Assembly of engine and exhaust system (as ready-made element)	13	x	x	13
10B	Subassembly of engine and exhaust system module	x	x	9	9
11	Assembly of suspension (as ready-made element)	13	x	x	13
11B	Subassembly of suspension module	x	x	4	4
12	Assembly of bumpers	x	x	9	9
14	Assembly of wheels	x	109	x	109
15	Assembly of seats	x	x	9	9
16	Assembly of steering wheel with air bag	x	12	x	12
17	Fuelling and filling with operating fluids	x	12	x	12
20	Assembly of doors	21	x	x	21
	TOTAL [s]	**60**	**231**	**54**	**345**

Again, like in variant I, components loading/unloading time has been disregarded. For seven out of nineteen production workplaces parts were delivered directly from the buffer warehouses. For the other workplaces direct deliveries (four workplaces) or in-time deliveries with one logistic train were employed. The other logistic train in this case is redundant, which additionally eliminates the costs of its maintenance and servicing.

4. COMPARISON OF RESULTS

The analysis of parts delivery times indicates a considerable difference (32%) between variants I and II. The time of supply parts to each assembly stations depending on system which was used in simulations is presented in Figure 4.

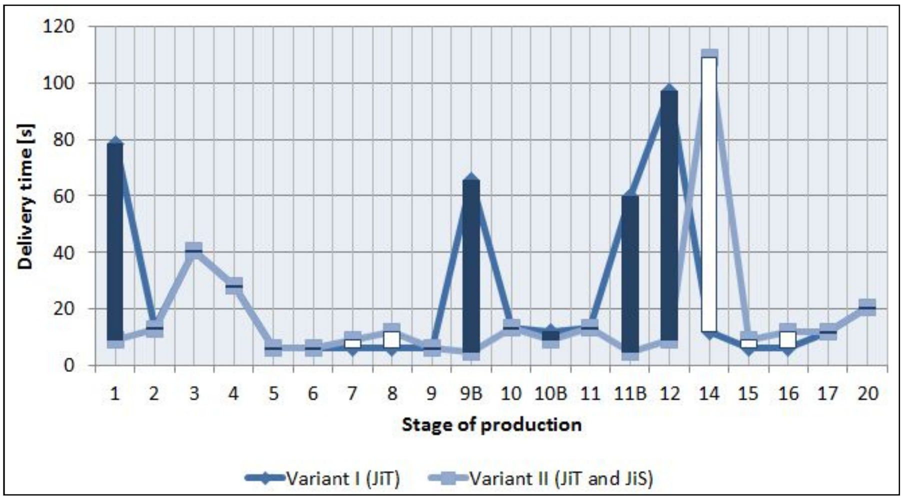


Figure 4 – Comparison of components delivery time to each stage in variants I and II

In the Figure 4 by blue column the decreasing of the time of supply parts to assembly station is showed. The increasing of that time is marked by white column. It is noticeable, that for almost all assembly stations that time were lower. Significantly increased the time of supply tires to the station of No. 14. To achieve better results for supply tires, it is recommended to supply it from main warehouse by logistic train in JiT system. For that case the supply tires from buffer parts warehouse is not effective.

Figure 5 illustrates the comparison of the two variants including the duration time of direct deliveries from the main warehouse, in-time deliveries with a logistic train and direct deliveries from buffer warehouses located by the production line.

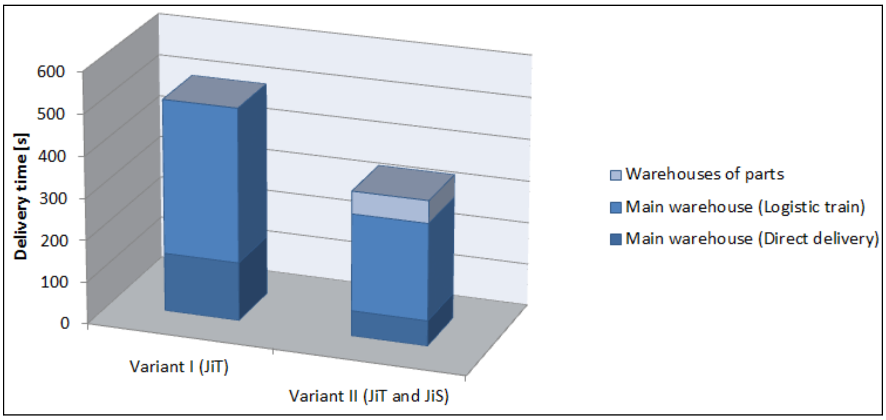


Figure 5 – Comparison of components delivery time to production line in variants I and II

JiS deliveries considerably reduce warehouse stock and the distance necessary to deliver components to the production line.

5. CONCLUSIONS

JiS deliveries require additional buffer warehouses, but they significantly reduce the stored stock and the distance necessary to deliver components to the production line. Moreover, they enable the reduction of the number of logistic trains, which reduces overall costs. It should be remembered that since in JiS delivery systems parts are delivered directly to the production line, in case of any delays in delivery from the outside stoppage of the production line may result. To avoid such a scenario, some stock of strategic components in the main warehouse is recommended.

6. REFERENCES

[1] Report SDCM, *Jaka naprawdę jest branża motoryzacyjna w Polsce.* Know-how, produkcja, dystrybucja, usługi – raport 2010, http://www.motoryzacjawpolsce.pl/pliki/raport_SDCM.pdf,02-01- 2015.

[2] Lorenc, A., Szkoda M.: *Customer Logistic Service in the Automotive Industry with the Use of the SAP ERP System.* Proceedings of: 2015 4th IEEE International Conference on Advanced logistics and Transport (ICALT), 20–22 May 2015, 18–23.

[3] Lorenc, A., Więcek P.: *The routes optimization of picking up commodities in stock considering their natural characteristics*, CLC 2013: Carpathian Logistics Congress – Congress Proceedings, TANGER Ltd., Ostrava, 2014, 307–312.

[4] Lorenc, A., Szkoda M.: *Zastosowanie systemu SAP ERP do obsługi dostaw Just-in-Time oraz Just-in-Sequence w branży motoryzacyjnej*, Logistyka 3 (2015), 2877–2886.

[5] Lorenc, A., Michnej M., Szkoda M.: *Information system aiding the logistics processes of loading and securing in railway transport*, International Journal of Shipping and Transport Logistics, 8 (2015)5, 568–589 (in press).

[6] Bergen, M.E., van Beek P., Carchrae T.: *Constraint-based Vehicle Assembly line Sequencing,* AI '01 Proceedings of the 14th Biennial Conference of the Canadian Society on Computational Studies of Intelligence: Advances in Artificial Intelligence 2001.

[7] Chattong, J., Hassamontr J.: *Integrated production planning scheme for car manufacturing operations*, Proceedings of MIM 2002: 5th International Conference on Managing Innovations in Manufacturing (MIM), Milwaukee, Wisconsin, USA, 2002.

[8] Malaki, A.A.*: A study of the effects of operational time variabilty in assembly lines with linear walking workers*, Thesis Work, Tekniska Kögskolan, Högskolan i Jöönköpig, 2012.

[9] Emde, S., Gendreau M.: *Scheduling in-house transport vehicles to feed parts to automotive assembly lines*, CIRRELT, Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation, 2015.

[10] de Jong R.: *Designing mixed-model assembly lines: a literature review*, Delft University of Technology, 2009.

IMPLICATIONS OF SEISMIC HAZARD IN JAPAN ON TOYOTA SUPPLY CHAIN DISRUPTION RISKS

Joanna R. MARSZEWSKA

Jagiellonian University, Kraków,
Poland

Abstract

This paper discusses disruption risks of Toyota supply chain implied by seismic hazard in the area, where major suppliers and assembly plants are located. Based on seismic hazard map of Japan and the two recent: 2011 Tōhoku and 2016 Kyūshū earthquakes, the supply chain disruption causes and effects are analyzed. The findings indicate that due to limited area for potential plant locations and transportation links in Japan, the supply chain decision-makers can hardly account for seismic risks.

Keywords:

seismic hazard; disruption risks; supply chain design; plant location, Toyota supply chain

1. INTRODUCTION

Supply chains disruption risk management has become a vital part of supply chain management strategy. The low-probability and high-impact flow disruptions and the resulting losses may threaten financial state of firms. Japan is considered to be the most dangerous spot in the whole world that is exposed to the various natural disasters. For example, the disruptive events that occurred in 2011 in the automative and electronics supply chains resulted in huge losses of major automakers and electronics manufacturers, e.g., [1–6]. Japan (for a tectonic map of Japan, see Figure 1) lies along the western part of the Pacific Ring of Fire, which is tectonically still unimaginable active place on the Earth. Japan, in the central part of the main island Honshū, is divided by two tectonic plates: North American (NAP) and Euroasian (EuP) and laying along connected with them, in two Triple Junctions, two others: Pacific (PP) and Philipino (PhP) from the East. Along the west boudary of the Pacific and Philipino Plates run the deepest trenches. This is place of plates collisions and every their shift cause thousands of earthquakes every year. But most of them are imperceptible. However at those subduction zones can occur unpredictable megathrust earthquake. Landform along the Japanese islands also is very complicated because of the great number of faults [7]. These faults occur in continuity that form tectonic zones like Fossa-Magna and Niigata-Kobe on Honshū. In the middle of the main island runs a major fault in Japan Itoigawa-Shizuoka (Itoigawa-Shizuoka Tectonic Line = ISTL) and Median Tectonic Line (MTL) which is the longest fault system in Japan. The beginning of MTL is in the area of Fossa-Magna, and runs from the central part of Japan passing Kii Peninsula and Shikoku Island to the south of the central part of Kyūshū. This zone is divided into six regions of expected seismic activity of magnitude 7 to 8 on the Richter scale. The recent (April 2016) earthquake with epicenter on Kyūshū is an egample of the very serious danger which can have its effects in continously chain earthquake along MTL and reach the area even near Tōkyō. As an example, a magnitude 6.2 foreshock struck Kumamoto on April 14 and then a magnitude 7 mainshock hited on April 16, 2016. In the next days more than 100 aftershoks occurred on Kyūshū island causing losses among the people (about 50 dead), geological deformations in landscape, collapse of buildings and disruption in communication. As a result of activity of crust movements several volcanic belts [8] extend along Japan Islands and trenches. The number of active volcano is about 100 [9] Among them the most dangerous volcanos are situated on Kyūshū, in the middle part of Honshū including Mt. Fuji and in the north part of Japan. Any of probable eruption is connected with great amount of volcanic ashes fallout and its range which is mostly depending on the wind direction. Volcanic bombs are also regarded as a danger in area of eruption. In such conditions Japan is exposed to many hazards from nature. But not only the location causes those dangers. Climate and various atmospheric phenomenons also have a very big impact on safety in Japan. Natural hazards that occur in Japan can be: earthquake, *tsunami*, volcano eruptions, *taifū* (typhoon), floods, landslides, winter monsoon or sometimes connected with them fires. It is very difficult to choose/decide the safety place for industrial investment in Japan also because of landform of this country, which has about 80% of mountains.

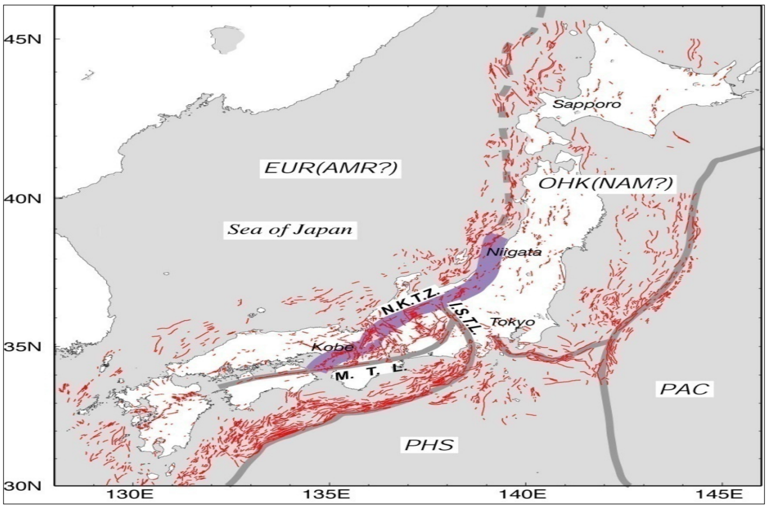


Figure 1 – Tectonic map of Japan [7]

The purpose of this paper is to analyze the implications of seismic hazard on plant location and logistics decision-making in the automotive industry in Japan. The paper is organized as follows. The description of selected hazardous regions in Japan is presented in Section 2. The major earthquakes in Tōhoku (2011) and Kumamoto (2016) regions are analyzed in Section 3 and final conclusions are made in Section 4.

2. DESCRIPTION OF SELECTED HAZARDOUS REGIONS

2.1. Aichi Prefecture

Near Aichi Prefecture about 100 km from the shore lies Nankai Trough (NT), which marks a subduction zone of Philipine Plate beneath Amurian Plate, part of Eurasian Plate. There is very dangerous and extensive fault situated under NT, which is divided into three zones of possible megathrust earthquakes. The zones are Tōkai, Tōnankai and Nankai. The two last areas are additionally divided into two more stretches each of them. In total in these three zones they create five segments, which are seismically very active. Depending on epicenter of shake in the fault in an affected area of coastal region "Pacific Belt" (zone of megalopolis running mainly along the Pacific coast) a damaging *tsunami (*megatsunami*)* may occur. The risk of Nankai earthquake in the near future is very high. According to the historical records earthquakes in this region occur with a return period of about 150 years and all of them have resulted in devastating *tsunami*. In case of quake with epicenter in Nankai fault it is highly probable that *tsunami* can enter seaside area of Aichi Prefecture. For Toyota it would be a serious impact on supply chain (for location of Toyota plants, see Figure 2). The last one Tōnankai Earthquake, a magnitude 8.1 occurred in 1944. Toyota Motor Corporation has its plants mostly in Aichi Prefecture. The main headquarter Honsha is located in Toyota city which is the largest city in this region. It is situated inland about 35 km from Nagoya, toward the mountains. Near Honsha there are six plants like Motomachi, Kamigo, Takaoka, Tsutsumi, Teiho and Hirose.

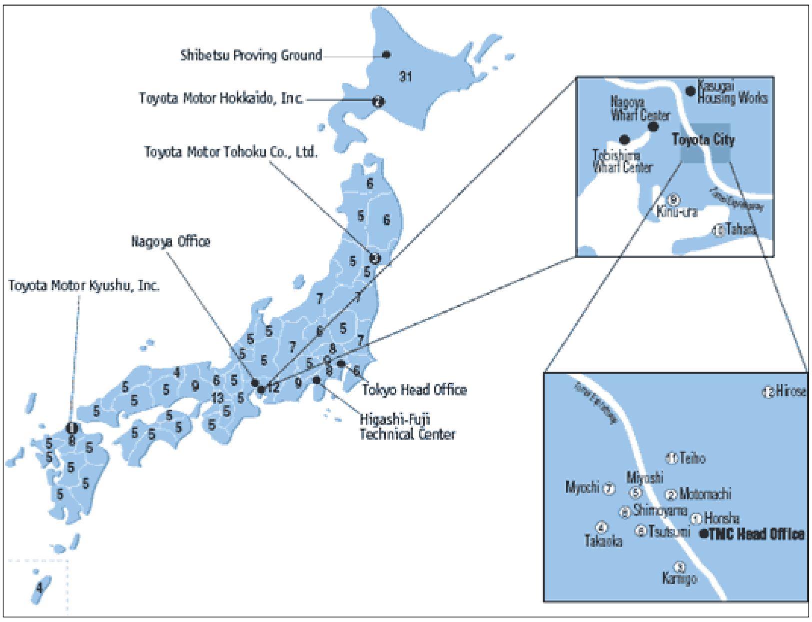


Figure 2 – Location of Toyota plants [10]

At other location between Toyota city and Nagoya there is Miyoshi city with three plants Miyoshi, Myochi and Shimoyama. And there is Kinu'ura Plant in Hekinan city in some distance from Chita Bay and Tahara Plant in Tahara city situated on Atsumi Peninsula. Toyota Auto Body Cooperation has its two plants (Kotobuki New Development Center and Yoshiwara) in Toyota city, two other (Kariya and Fujimatsu) in Kariya city. And in the neighboring prefecture of Mie has Inabe Plant in Inabe city and at the greater distance in Gifu Prefecture, Gifu Auto Body Honsha. Most of the factories are located far from the sea and are not exposed to possible *tsunami* caused by quake. But there are two exceptions of Hekinan and Tahara, both situated not so far from the sea. It should be mentioned that after 2011 Tōhoku Earthquake, *tsunami* was observed in the coastal region along Japan Archipelago, including neighborhood of Nagoya when waves reached a height of 1.6 m in Tahara and 1 m in Nagoya [11].

Moreover, Mediana Tectonic Line, the longest fault system in Japan, runs near Mt. Hōrai, Toyokawa city and along Atsumi Peninsula, all in Aichi Prefecture. It is also very dangerous because it is active zone. In 1995 Great Hanshin Earthquake hit Kobe causing many damages. It's epicenter was in Nojima Fault, one of MTL faults system. Such configuration can occur devastating earthquakes.

It seems that even if the strong earthquake occur in Nankai Through and cause high tsunami, most of the Toyota Group plants will be safe because of distance from the sea. But there are two locations of plants Tahara and Heikinan in serious danger. Another reason of hazards is in Mediana Tectonic Line. If epicenter will be in that fault in Aichi Prefecture losses can be unpredictable huge for surrounding area including Toyota and other plants. Damages to roads and bridges may cause interruption of the supply chain.

2.2. Tōhoku Region

This region is exposed to natural disaster because of location to Japan Trench, part of the Pacific Ring of Fire. This is zone of subduction of Pacific Plate under Okhock Plate (bounded on the north by the North American Plate) and continuing movement of the plate can causing *tsunami* after quakes. Moreover in Miyagi Prefecture area there are several active faults. Toyota Plants (Toyota Motor East Japan Inc.): Kanegasaki, Iwate prefecture, Ōhira, Taiwa, Miyagi Prefecture. Kanegasaki is located inland in the valley / plane between the mountains. This place is far from the sea and it is safe from *tsunami*. But in this area there is active Kitakami Teichi Seien fault zone in which can occur afterquake caused by mainquake with epicenter in Japan Trench. Aftershakes may cause damages in landform. Roads cracks, bridges collapse, landslides, liquidation of soil – all of this interrupted supply chain for Toyota Plants. Ōhira village lies near Taiwa town, both located in Miyagi Prefecture in about 20 km from the coast. This area after 2011 Tōhoku earthquake was safe from *tsunami*, but was affected by many interruptions of roads (see, Figure 3).

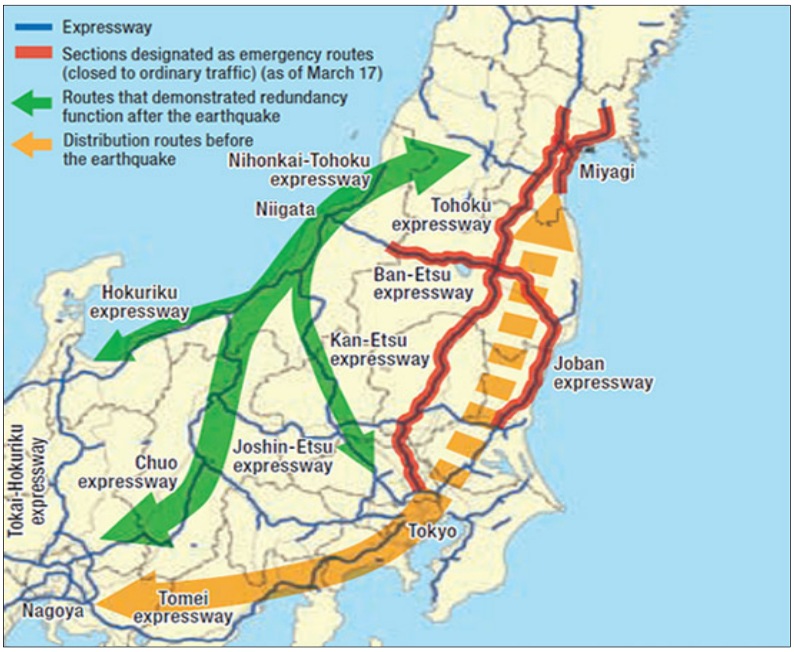


Figure 3 – Distribution routes in Tōhoku [12]

2.3. Kyūshū Island

Kyūshū is considered a " Silicon Island" and a "Gateway to Asia". Because of competitive prices of land, easy access to clear water and relatively cheaper labor, and proximity to the other asiatic countries, Kyūshū has become a manufacturing hub. The other reason is that, island is not so big but has seven airports, and twelve major seaports serving many international scheduled container liners, approximately 1000 km of expressways and major arteries and well developed railroad network [13].

Kyūshū Island in its landscape is abound in mountains with a large number of volcanoes. Some of them are recognized as the most active and dangerous in Japan, even in the world. These include Unzen, Aso, a complex volcano forming a very large caldera of 24 km with many active vents, Kirishima, group of eighteen volcanos, Sakurajima, continuously active volcano which is treated as one of the most active volcanoes in the world, and some others. Moreover, in the east-central part of island there is Usuki-Yatsushiro Tectonic Line, continuation of Mediana Tectonic Line starting from the central part of Honshū. This area is splitted in two main active faults being in not so far distance, Futagawa and Hinagu. Kyūshū is also a part of Kyūshū – Palau. These undersea mountains separate trough into Nankai Trough and Nansei Shotō Trough. Earthquakes occur mostly in area of faults and active volcanoes and in the off coastal subduction zone. Toyota Motor Plants of Kyūshū are located in the north part of island in Kitakyūshū, Kokura and Kanda, all are in the vicinity. Only Toyota supplier plants such as Aishin Seiki and Renesas are located in the seismically dangerous area near Hinagu fault.

3. TŌHOKU AND KUMAMOTO EARHQUAKES IMPLICATIONS

3.1. Tōhoku Jishin (Tōhoku Earthquakes) case 2011

Toyota was seriously affected in 2011 by devastating earthquake and *tsunami* in the northen part of Japan. Hypocenter of Tōhoku Earthquake was only about 130 km from Sendai and 72 km from Oshika Peninsula at shallow depth of approximately 32 km. The earthquake caused devastating damages in whole area of Iwate, Miyagi and Fukushima Prefectures. The earthquake moved the main island of Honshū about 2.4 meters and shifted the planet on its axis by nearly 10 cm. *Tsunami*, depending on the region and place, caused about 10 m walls of waters, and somewhere reached 10 km. Renesas Electronics Corp, producer of microcontrollers used in automobiles located in Ibaraki Prefecture was devastated and Toyota supply chain was severely affected [14]

In this region there are many small factories producing small parts for another suppliers. Toyota Motor Corp spent many weeks to indentify how its suppliers had been affected by the quake [14]. Most of he roads in affected area were designed as emergency routes and that why were closed to other movements [15]. Thus it is very important to make analysis of the effects of probable natural disasters on the roads and introduce new technologies for newly constructed road systems with new control methods. After the Tōhoku 2011 earthquake assembly plant in Miyagi Prefecture has been evacuated. This plant was producing Yaris sedan The other assembly plant – Kantō Auto Works has also been evacuated; Toyota had to evacuate also several part supplier factories in quake zone, including two plants producing parts for cars assembled in Tōhoku [16]. Toyota car production after Tōhoku 2011 Earthquake plummeted 62% due to only power shortage, damage of buildings of factories and lack of parts supply[17].

3.2. Kumamoto Jishin (Kumamoto Earthquakes) case 2016

An example of Kyūshū earthquake of 6 and 7.0 magnitude (April 14 and 16, 2016) which hit Kumamoto at about 21:30 pm and 1:30 am is showing how only in a few days, many strong aftershocks, can change a natural environment of the island.

Japan's Meteorological Agency, which is observing all natural hazards in Japan has detected about 500 – 600 tremors in the middle of Kyūshū. It's also warns that seismic activity may be continuous and can appear as a chain of migrating eastward quakes's epicenters[18] along the end of MTL.

In two days after devastating quakes many building collapsed in affected area and there were also many landslides. One of the greatest landslide tore destroyed a key bridge, Great Aso Bridge for Minami Aso village. That cut off all land transportation.

As a result of such destructive earthquake and numerous afterquakes Toyota stopped its car production in whole Japan. Supply chains were disrupted and because of this most of assembly lines of Toyota plants had to be shut down as well as parts suppliers. Toyota factory was shut for a week and lost about 50 000 vehicles, including brands such as Prius, Lexus, Land Cruiser.

As it is seen in the map (Figure 4) all quakes on Kyūshū in this time formed a pattern of strait line dividing island in two isolated parts.

The recent earthquakes, which occurred in Kyūshū area have a devastating effects on manufacturing supply chain for various branches of industry. Kyūshū, for a long time, was and still hope to be a place of many factories of components. Among them there are factories producing most important automobile parts for Toyota and other company.

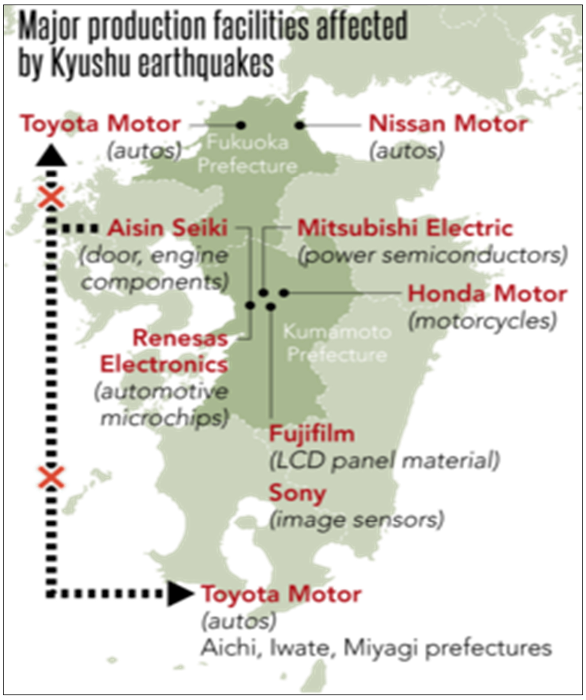


Figure 4 – Affected Kyūshū plants [19]

The series of strong earthquakes hit like a sucker punch and had paralyzed much of the region's transportation networks [19]. Landslides damaged many highways. For example, Aisin Seiki plant was completely destroyed in Kyūshū. The ceiling was collapsed and destroyed among others production lines. As a result supply chain for Toyota was disrupted and plant situated in Fukuoka had to suspend its production of Lexus luxury cars.

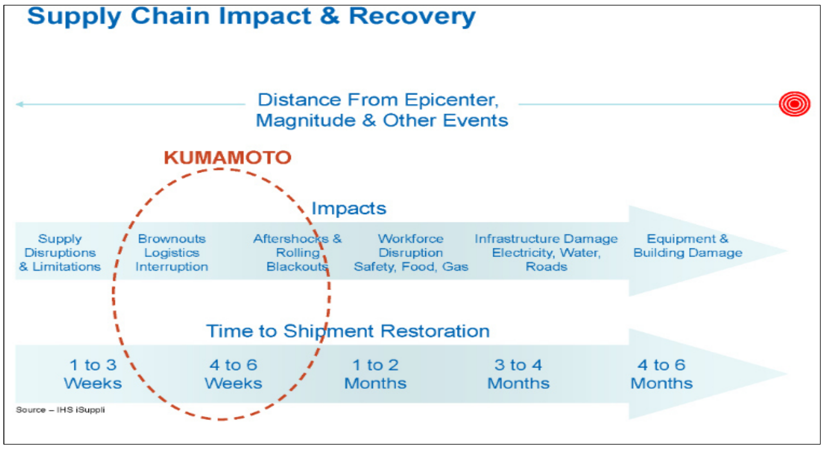


Figure 5 – Time-to-Recover after Kumamoto earthquake [20]

In the first days after earthquakes Toyota was the most affected plant because its lost their key suppliers like Aisin Seiki and Renesas. Aisin Seiki's products: body, engine components – three factories in Kumamoto Prefecture – two of them had to halt their operations which were crucial for Toyota Group [21]. Renesas key product are semiconductors for Toyota engine (microcontrollers). Recovery plan was announced in April 21, 2016 [20]. Renesas Kawashiri plant on Kyūshū – Renesas Electronics' Kawashiri plant Renesas Electronics' – experienced damage (many chemicals like gases used to maintain the antiseptic conditions for chips and integrated circuits became very dangerous, etc. [22]. However, Toyota announced in April 20, 2016, that some of production will be resume at some plants despite of destructions. Among the other automobiles producers Toyota and Toyota Group were the most affected plants because of its heavy reliance on supplies from Aisin Seiki and Renesas. The whole recovery was expected in months (see, Figure 5).

Finally, it is worth to notice that this year Toyota had to suspend their domestic assembly lines for the second time due to the explosion in one of the affiliated steel plant, Aichi Steel in February 8–13 [20].

4. CONCLUSIONS

Main locations of the most important factories are in endangerous area like Toyota City in Aichi Prefecture, near Nankai Trough (NT) or in the north of Honshū in Miyagi Prefecture. It is very difficult to find good area for facilities because Japan has only about 20% of flatland area available for such investments. It seems that the safest regions lie near Sea of Japan. But because of mountain formation it is very difficult to find proper area for industry. On the other hand, according to records in the Nankai Trough area, earthquakes occur roughly every100–150 years, and now a very dangerous time for that is approaching. Lessons learned from the previous earthquakes 2011 and 2016 give very important hints how to prepare to recover quickly from unexpected disaster and how to be able to minimize deleterious effects on the supply chains. For example, lessons learned from Tōhoku Earthquake 2011 [22] imply necessity of creation of new business continuity plans that allow to restore to the normal operations within one month and prepare restructuring plans to be in place that allow to create surplus production, when it is needed. The future research should concentrate on location analysis under uncertainty (e.g. [23]) of suppliers, assembly plants and transportation links in hazardous areas, improving supply chain resilience by fortification of key suppliers and pre-positioning of emergency inventory of critical parts (e.g. [24]), and on integration of decision-making under disruption risks (e.g. [25]).

5. REFERENCES

[1] Park, Y., Hong P., Roh J.J.: *Supply chain lessons from the catastrophic natural disaster in Japan*, Business Horizon, 56(2013), 75–85.

[2] Fujimoto T., Park, Y.W.: *Balancing supply chain competitiveness and robustness through "virtual dual sourcing": lessons from the Great East Japan Earthquake*, International Journal of Production Economics, 147(2014), 429–436.

[3] Haraguchi, M., Lall U.: *Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making*, International Journal of Disaster Risk Reduction, 14(2015), 256–272.

[4] Matsuo, H.: *Implications of the Tohoku earthquake for Toyota's coordination mechanism: Supply chain disruption of automotive semiconductors*, International Journal of Production Economics 161(2015), 217–227.

[5] Tatsumi, Y., Suzuki-Kamata K.: *Cause and risk of catastrophic eruptions in the Japanese Archipelago*, Proc. Jpn. Acad., Ser. B (90)2014, 347–352.

[6] MacKenzie, C.A., Barker K., Santos J.R.: *Modeling a severe supply chain disruption and post-disaster decision making with application to the Japanese earthquake and tsunami.* IIE Transactions, 46(2014), 1243–1260.

[7] http://cais.gsi.go.jp/Virtual_GSI/Tectonics/Niigata_Kobe/niigata_kobe.html

[8] https://www.numo.or.jp/en/reports/pdf/Level3_SF_Final-09.pdf

[9] http://www.data.jma.go.jp/svd/vois/data/tokyo/STOCK/souran_eng/appendices/volcano_list.pdf

[10] http://toyota-club.net/files/2004/04-01-10_rem_japan-1.htm

[11] https://en.wikipedia.org/wiki/2011_Tōhoku_earthquake_and_tsunami#/media/File:Tsunami_map_Tohoku2011.svg

[12] http://www.e-nexco.co.jp/english/business_activities/construction/city_network.html

[13] http://www.kyushu.meti.go.jp/seisaku/kokusai/toushi/data/en/5koutuinfura2.pdf

[14] http://www.reuters.com/article/us-japan-quake-supplychain-idUSKCN0WW09N

[15] http://www.e-nexco.co.jp/english/business_activities/construction/city_network.html

[16] http://www.cnet.com/roadshow/news/quake-hobbles-japans-auto-output/

[17] http://thoughtleadership.aonbenfield.com/documents/201108_ab_if_japan_eq_tsunami_event_recap.pdf

[18] http://asia.nikkei.com/magazine/20160421-AFTERSHOCKS/On-the-Cover/Economic-aftershocks-spreading-well-beyond-Kyushu

[19] http://asia.nikkei.com/Politics-Economy/Economy/Kyushu-quakes-highlight-island-s-key-place-in-global-supply-chain

[20] https://www.linkedin.com/pulse/kumamoto-japan-earthquake-its-impact-electronics-supply-dale-ford

[21] http://blog.ihs.com/kyushu-earthquake:-the-immediate-impact-on-the-japanese-automotive-industry

[22] http://naplesherald.com/2016/04/18/disruptions-twin-quakes-southern-japan-hit-economy/

[23] Snyder, L.V.: *Facility location under uncertainty: A review*, IIE Transactions 38(7)(2006), 537–554.

[24] Sawik, T.: *Selection of resilient supply portfolio under disruption risks*, Omega 41(2013), 259–269.

[25] Sawik, T.: *Integrated supply, production and distribution scheduling under disruption risks*, Omega 62(2016), 131–144.

EFFECTS OF TRANSPORT LOGISTICS ON LOCAL DEVELOPMENT IN SERRA, BRAZIL

Daniel MUNIZ[1], Maria FAE[2]

[1,2]Universidade Federal do Espírito Santo, Programa de Pós-Graduação em Geografia,
Campus Universitário Goiabeiras, Vitoria, Espirito Santo,
Brazil

Abstract:

This article aims to identify and analyze possible location advantages and disadvantages in Serra, a municipality with a significant growing economy despite the Brazilian crisis. Nowadays Serra faces a change in the profile of industrial to a mixed economy, and a reduction in enterprises. Gross Domestic Product and the number of jobs remain increasing and were unaffected by enterprises reduction. In 2011, 0.3% of a sample of 38 big enterprises was responsible for 16.4% of jobs and about 60% of GDP. Data was also analysed by regression. Logistics in transport is important in location choice and determinant in Serra's economy.

Keywords:

transport logistics, economic development, industry location

1. INTRODUCTION

There is a vast literature on location choice of facilities. The methods usually comprise analytic techniques, linear programming, and simulation [1]. Sometimes a method applies better to an specific problem, sometimes the results given by different models are similar. The variable cost is usually determinant in the majority of the models analyzed. For instance, various models were developed to analyze the location of recycling industries of coconut residuals, in Brazil, and a mixed-integer nonlinear optimization model developed by [2] gave similar results as a regression model by [3] for the same problem.

Here, the aim is not to develop a location choice model, but to understand why a significant number of enterprises choose a place called Serra to locate their plant. This municipality belongs to the metropolitan area of Vitoria (RMGV), in the State of Espirito Santo, Brazil.

Serra has been in the spot of the national economic development. A remarkable change has been observed in its local economy since the installation and operation of a large mining company (Vale) in the 70's, followed by a steel plant (Arcelor Mittal Brazil). Serra's economy was mainly based in industries, however an actual change has been observed with the installation of warehouse facilities, public and private investments on logistics, among others.

Taking into account the expressive growth shown in Serra, the objective of this work is to identify and analyze possible location advantages and disadvantages faced by major companies in their location in the municipality Serra-Brazil. The analysis comprised the transport logistics of the region, tax incentives, population growth, gross domestic product, number of jobs, number of enterprises, and foreign trade. Regression was used to understand the behaviour of the variables. Although the focus of the data analysis concerned the municipality of Serra, regression was also undertaken for both the state of Espirito Santo and Vitoria, the capital of the State, to have a basis for comparison.

A sample of the 46 largest enterprises located in Serra were selected among those which presented high gross operating revenue in 2014: 21 of them belong to the service sector, 15 are in the industrial sector, 8 are of the wholesale, and 2 of the retail trade. These companies were then allocated in a spatially cartographic base containing the transportation logistics system. Small and medium enterprises are mainly linked to the commerce and service sectors, and are located around the big companies. The small enterprises are mainly family businesses without employees.

Brazilian policies on taxes reduction were implemented both in the local and national levels. In Serra, two of them showed important benefits: Fundap and Invest-ES. Fundap is dedicated to trade companies, and comprises a loan of the public sector with very low interest rates, provided that 9% of its value is invested in local projects that increase income and local employment. The other policy, called Invest-ES, concerns programs that offer different tax values and loans to any economic sector.

Serra became a privileged locus of new investments, with a prosperous economic situation as shown by its contribution to the Gross Domestic Product (GDP) of Espirito Santo State, in Figure 1.

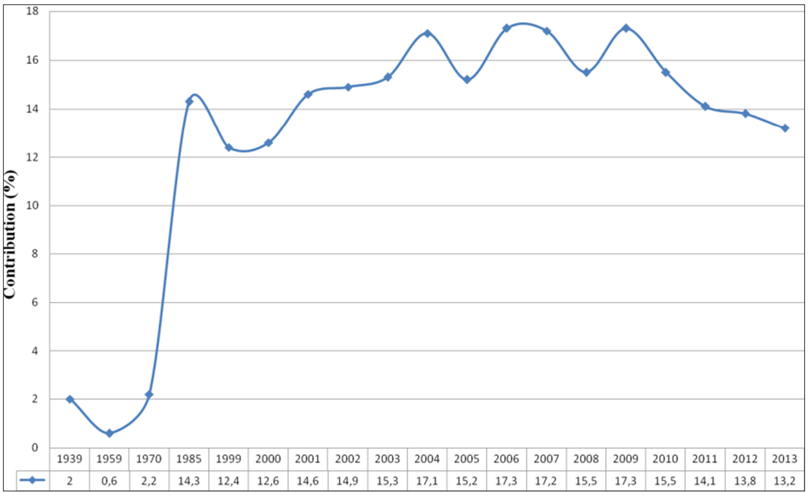
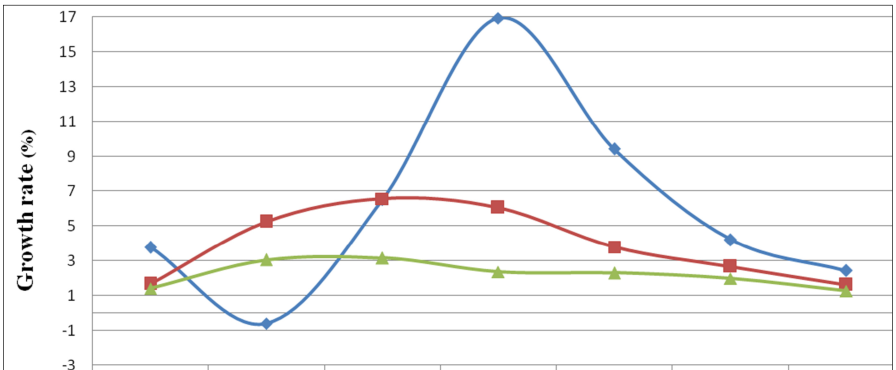


Figure 1 – Contribution of Serra in the GDP of Espírito Santo State

In the 70's, Serra was responsible for only 2,2% of the GDP of Espirito Santo State. In 1985, its contribution increased to 14.3%, and in the following decade remained highlighted due to its growth in different economic sectors.

Vitoria, the capital of the Espirito Santo State, presented a GDP of $ 1.6 million in 1999 and $ 6.3 in 2013. Today Vitoria has the highest GDP among the municipalities in Espirito Santo, followed by Serra.

Since 1970 Serra has a population growth that is above the mean value of Espirito Santo State, as shown in Figure 2. The geometric mean rate of its annual population growth gives an average increase of about 17 people for each group of 100 inhabitants, for the period 1970–1980. This population growth is above the one presented by both RMGV (6%) and Espirito Santo State (2%).



	1940-1950	1950-1960	1960-1970	1970-1980	1980-1991	1990-2000	2000-2010
Serra	3,79	-0,6	6,52	16,93	9,42	4,22	2,45
RMGV	1,68	5,26	6,58	6,07	3,8	2,68	1,62
ES	1,42	3,06	3,17	2,38	2,31	1,98	1,27

Figure 2 – Geometric mean rate of annual population for Serra, RMGV and Espírito Santo

The annual population growth in Vitoria is around 1.2%. It is smaller than Espirito Santo and Serra probably due to land and housing prices, and people's economic level.

Up to 2000, most of the population living in Serra comprised low income people and labourers of large enterprises. Since 2000, people's status begins to change into the middle-class, whose demand lead to a real estate product directed to the market. From 2001 to 2009, the requirement for housing construction was attended by 19 civil engineering companies and 156 projects [4].

Serra has an area of about 552 km^2 that represents about 23% of the total area of the metropolitan area (RMGV). Between 1970 and 2013 the urbanized land of Serra showed a significant growth. Nowadays it represents a significant percentage of the effectively urbanized area of the metropolitan region-RMGV, as shown in Table 1.

Table 1 – Land occupation in Serra and in the metropolitan region – RMGV

Year	RMGV – land occupied (km^2)	Serra – land occupied (km^2)	Serra/ RMGV (%)
1970	57.55	7.53	13.08
1998	215.56	67.98	31.54
2013	296.66	96.00	32.36

In 1970, the urbanized area of 7.53 km^2 represented only 13.08% of the occupied metropolitan region-RMGV of 57.55 km^2. Between 1970 and 1998, a significant increase of occupation was mainly observed along the cost and in dispersed suburbs (67.98 km^2). Figure 3 illustrates a dense and continues occupation by 96 km^2, in 2013.

Serra has a strategic geographical position and an important logistics infrastructure for foreign trade. The construction of the main transportation system was completed before 1970, and after that there has been some expansion and modernization.

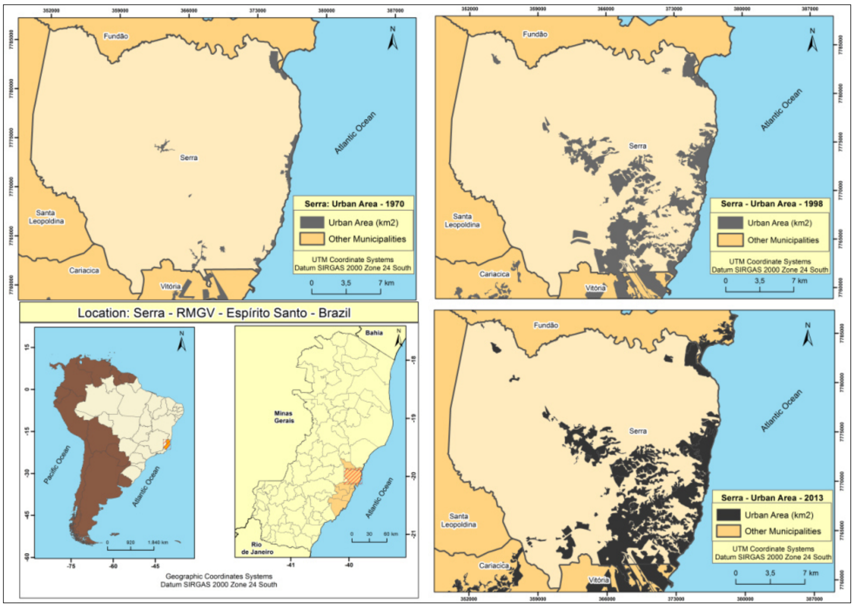


Figure 3 – Serra: location and land occupation in 1970, 1988 and 2013

Figure 4 shows the main transport network in analysis and the enterprise conglomerations. A highway named BR101 cross the Espirito Santo State from South to North, in a large portion of Serra's territory. The road ES-010 allows the connection of many enterprises conglomerations to the Highway BR101, and also provides a link to resort areas located along the ocean cost.

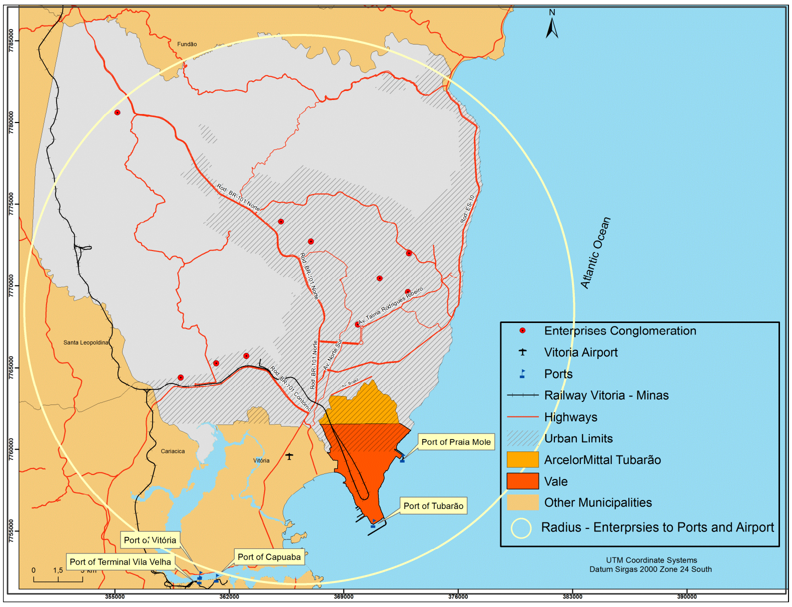


Figure 4 –Transport infrastructure and enterprise conglomerations in Serra

There are five ports for commodities. A railway connects the ports to hinterland areas of iron mining and the fields of soy plantation in the western parts of Brazil. The airport infrastructure almost attends the demand of passengers and cargo, mainly electronic supply among other. Expansion is on course.

Serra has ten enterprise conglomerations that occupy 29,000 km^2 all together, close to the railway and the roadways, as shown in Figure 4. They comprise many warehouses, a multimodal industrial terminal that shelters an integrated supply centre of national and international trade, among others [5]. Enterprises conglomerations are located at 16 km of the main ports and airport of the region. Most of the enterprises in Espirito Santo are situated in RMGV.

To understand the connection of the elements presented above and the choice of location of enterprises in Serra, data are analysed in the following section.

2. ANALYSIS

Data concerning Serra are initially presented and analysed, followed by the data analysis of Espirito Santo and Vitoria.

Table 2 contains the data regarding Serra, for the period 2002–2013. The description of the variables is:

- Number of enterprises – number of enterprises in Serra/year
- Jobs – number of people employed in Serra/year
- Import – amount that is imported by Serra (US$ FOB)/year
- Export – amount that is exported by Serra (US$ FOB)/year
- Population – Economically Active Population in Serra/year
- GDP – Gross Domestic Product in Serra (US$)/year

The number of enterprises increased by almost 51% during the period 2002–2010. This represents an increase of 4641 enterprises. A reduction of 5721enterprises was observed in the short period from 2010 to 2013, most probably due to the 2008 crisis. However, the number of jobs does not seem to be affected by the enterprises reduction, since it remained growing with an increase of 74,899 employments over the period 2002–2013.

Table 2 – Social and economic data of Serra, 2002–2013

Year	Enterprises	Jobs	GDP (US 10^3)	Importation Serra US$ FOB x 10^5	Exportation Serra US$ FOB x 10^5	Population
2002	9,154	58,350	1,131,118	482.4	937.2	261,563
2003	9,635	63,955	1,343,155	503.1	972.3	268,956
2004	10,032	66,364	1,952,505	591.8	1,234.3	276,334
2005	10,651	86,868	2,037,089	964.4	1,432.2	293,075
2006	10,993	92,406	2,888,592	900.9	1,626.8	301,603
2007	11,574	95,151	2,949,282	990.2	1,648.8	313,115
2008	12,353	103,255	3,062,213	1,620.2	947.9	307,173
2009	13,275	108,645	3,266,129	762.0	1,501.8	313,454
2010	13,795	116,544	3,599,242	1,908.2	1,802.5	325,489
2011	11,274	126,635	3,891,856	2,583.6	1,725.7	330,866
2012	10,953*	128,909	4,210,380	2,092.7	1,384.4	336,068
2013	8,074	133,249	4,377,332	1,789.0	1,241.8	346,915

*Estimated

This fact has probably happened because most of the big companies remained in the market despite de crisis. For instance, in 2011 a very small number of 38 big enterprises, representing 0.3% of the total 11,274, were responsible for 20,797 jobs in Serra (16.4% of 126,635) and about 60% of GDP [6].

Importation and exportation were approximately in line with the enterprise variation, but around 2008–2009 some variations were clearly shown with important decreases by both. In 2010, importation and exportation presented some growth, but remained decreasing in 2012 and 2013. Despite the behaviour of the previous variables, GDP remained growing all over the years.

Regression was also used to better understand the interrelation among the variables. The best result was obtained using Jobs as independent variable, and GDP and Import as dependent variables – equation (1). The *t*-student gave 7.6 for the intercept, 8.5 for GDP and 1.7 for Import. R^2 adjusted equal 0.96.

$$JOB = 31{,}823 + 0.02GDP + 0.62IMPORT \tag{1}$$

The inclusion of the variable Enterprise did not give good results, most probably due to the fact that less than 1.2% of the enterprises supply approximately 48% of all jobs. In other words, a small number of enterprises generate a large amount of revenue and jobs in Serra.

Around 1/3 of the medium and small enterprises of Serra belong to families and do not have employees [7].This is probably the reason why the variable enterprise was not significant in the regression. Population was also not very significative in the regression, and it was disregarded. Similar analysis carried out for the State of Espirito Santo highlights the importance of Serra in this context. Table 3 contains some data of Espirito Santo, for the period 2002–2013.

The behaviour of importation and exportation in Espirito Santo were approximately similar to the ones shown in Serra, however the variation occurred around 2009–2010, and important decreases were in 2012 and 2013. As observed in Serra, the GDP in Espirito Santo remained growing most of the years, apart a slight decrease in 2009. The variable jobs increased all over the years.

Table 3 – Social and economic data of Espirito Santo, 2002–2013

Year	Jobs	GDP (U$ 10^3)	Importation U$ FOB x 10^5	Exportation US$ FOB x 10^5
2002	551,601	7,585,634	2,019	2,597
2003	565,301	8,806,905	2,156	3,535
2004	593,593	11,402,074	3,011	4,055
2005	656,344	13,388,121	4,088	5,593
2006	707,380	14,963,014	4,896	6,721
2007	751,559	17,107,002	6,638	6,871
2008	776,290	19,808,977	8,606	10,099
2009	816,906	18,928,048	5,484	6,510
2010	860,421	23,282,443	7,595	11,954
2011	902,070	27,697,170	10,738	15,158
2012	928,431	30,428,887	8,698	12,160
2013	954,791	33,167,487	7,435	1,090

The best result found in the regression for Espirito Santo was obtained using Jobs as independent variable, and GDP and Import as dependent variables. The t-student gave 19.8 for the intercept, 6.6 for GDP and 1.4 for Import. R^2 adjusted equal 0,96. Equation 2 gives the relation among Job, GDP and Importation for Espirito Santo. The short name ES inside the brackets stands for Espirito Santo.

$$JOB(ES) = 432{,}916 + 0.01GDP(ES) + 9.27IMPORT(ES) \quad (2)$$

Regression was also applied to data of Vitoria municipality, capital of the State Espirito Santo. The data sample comprised the period 2002–2011, as shown in Table 4.

Table 4 – Social and economic data of Vitoria, 2002–2011

Year	Jobs	Importation x105	GDP x 103	Exportation x105
2002	109454	12271	2177005	11625
2003	110259	13651	2388973	12819
2004	115303	20623	3350382	16219
2005	124525	26138	4478761	19502
2006	132183	34186	4671140	24270
2007	140175	43726	5430046	22155
2008	147998	56423	6553941	49502
2009	149795	37120	5598631	21680
2010	158426	43183	7078686	42607
2011	165812	62159	8039595	50788

The regression results showed that both import and export variables were not very significative to explain the behaviour of jobs, despite the R^2 adjusted equal 0.96. The variable Export gave a slight better result, so it was considered in the regression. Equation 3 shows the regression using data of Vitoria municipality. The short name Vit inside the brackets stands for Vitoria.

$$JOB(Vit) = 83{,}124 + 0.01GDP(Vit) - 0{,}24EXPORT(Vit) \quad (3)$$

The test t-student for the intercept is equal 20.8, for GDP 7.13 and for Export 1.1. The negative sign of export may represent a decrease in jobs in Vitoria with the exportation increase, what makes no sense.

Considering the regression results for Serra, Espirito Santo and Vitoria one may conclude that Serra overwhelms the group of Espirito Santo municipalities together, including Vitoria. The difference between exportation and importation in Serra is always higher that in Vitoria. The results for Espirito Santo are very close to the ones for Serra probably because this municipality represents the large part or the State Economy.

The role of logistics infrastructure is visually analyzed in the geographical space of enterprises conglomerations to identify the level of connection of flow materials and people (see Figure 5). The majority of the enterprises are located around 16 km of the main ports and airport. They are also located along the main roads BR101 and ES010.

For the analysis of taxes incentives an approximation may be the amount of exportation and importation of goods, since both programs, Fundap and Invest-ES, mainly attracted trade companies and, consequently, the international trade.

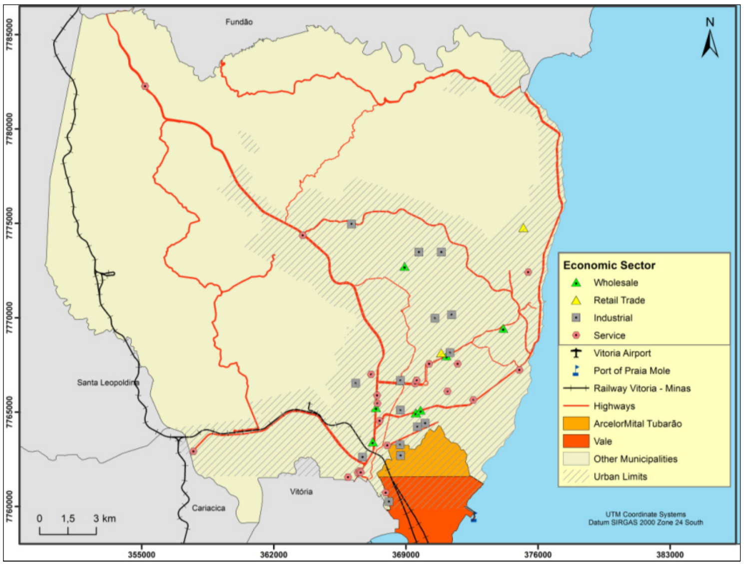


Figure 5 – Location of big enterprises in 2014

3. FINAL COMMENTS

Public incentives like Fundap and Invest-ES may have played a role in the boom concerning location of enterprises in Serra in the last decade, but this variable was indirect analysed by exportation and importation, and cannot be isolated.

A large amount of population came after the installation of the big industries (Vale and Arcelor Mittal), so enterprises were not attracted by employees living in Serra at that moment. By the kind of job specialization of the big enterprises, local population is not directly employed by them, particularly in the industrial sector, when compared to commerce or service. Local population mainly work on medium and small enterprises.

Initially, the industries came to Serra because they were attracted by logistics of transport (mainly railway and port) to attend commodity exportation. Later, in the 90's, logistic infrastructure remained the same, and the main attraction was tax incentives by the public sector, followed by extensive unoccupied land near the urban area and its surroundings with relatively affordable prices.

Nowadays an important attraction is the logistics given by the enterprises conglomerations, shown in Figure 4, in addition to improvements in the logistics of transport. The conglomerations have good infrastructure as concerns water and energy supply, residual collection and treatment, excellent information and communication technology, and good logistics in transport in a radius of 16 kilometres from the main railway, ports, roadways and airports.

4. ACKNOWLEDGEMENT

The authors would like to acknowledge the contributions given by Professor Angela Morandi, Professor Samir Aride and the Import and Export Trade Union of Espirito Santo – SINDIEX.

5. REFERENCES

[1] Burinskiene, A.: *Selection of warehouse place*. Proceedings of International Conference on Industrial Logistics 2014, Zagreb, Croatia, June 2014, 13–19.

[2] Ribeiro,G.M., Faé M.I.: *A mixed-integer nonlinear optimization model for location-allocation problem of recycling industries of green coconut residuals in Brazil*. Proceedings of 11th International Conference on Computers in Urban Planning and Urban Management, Hong Kong, 2009.

[3] Schwarts, A., Faé, M.I., Ribeiro, G.M.: *Um modelo de localização de indústrias de reciclagem*. Proceedings of Anpet, Fortaleza, Brazil, 2008, 68–78.

[4] Ferreira, F.C.: *Propriedade fundiária, os "vazios urbanos" e a organização do espaço urbano: O caso de Serra na região metropolitana da Grande Vitória-ES (RMGV-ES)*. Dissertação de Mestrado. PPGG, UFES, Brasil, 2015.

[5] PMS: Pólos empresariais, www.serra.es.gov.br/site/pagina/polos-empresariais, 01-04-2016.

[6] Morandi, A.M.: *Desenvolvimento Econômico da Serra*, in: Serra: Agenda do Futuro 2012–2032 Relatório Temático de Diagnóstico, FCAA, 2012.

[7] Morandi, A.M.: *Contexto Empresarial da Serra*, in: Planejamento Estratégico Agenda 21, 2007–2027, 2008.

ANALYSIS OF LOGISTIC PROCESSES USING THE SOFTWARE TECNOMATIX PLANT SIMULATION

Miroslav MUSIL[1], Vlastislav LASKOVSKÝ[2], Pavol FIALEK[3]

[1]Tomas Bata University in Zlín,
nám. T. G. Masaryka 5555, 760 01 Zlín,
Czech Republic
[2]Technical University of Kosice,
Slovakia
[3]Technical University of Kosice, Faculty BERG,
Letna 9, 042 00 Kosice,
Slovakia

Abstract:

Application of the simulation tools within the framework of a large spectrum of various logistic processes is becoming a common obviosity on the present. The simulation tool enables to obtain such information, which is unidentifiable in the current practice, however this information is a valuable informational source for a following evaluation of the logistic processes. This article presents analysis of a logistic system using the simulation model created by means of the software product Tecnomatix Plant Simulation.

Keywords:

simulation, transport, technology, sorting

1. INTRODUCTION

A massive wave of innovation in Germany is known as the fourth industrial revolution for the last 260 years, is based on the use of advanced information and communications technologies in all industrial areas of material handling through its processing to delivery of products to customers[1]. The ability to obtain the amount of data on actual processes and their treatment, giving researchers the opportunity to create a virtual image of industrial processes. This virtual image of reality provided by experimenting with real system in a virtual environment without the risks that would jeopardize the operation of real systems. If the real environment and the virtual world to spread the digital models and techniques that provide tools for dynamic analysis such as simulation, emulation, meta-modeling, there is a completely new type of environment. This type of environment has become a basic idea of Industry 4.0. 4.0 Industry philosophy became a hit the German economy. Part of such a philosophy is also a digital enterprise. It is a computer information technology, which replaces the real world model. Industry 4.0 is the theme of the future of digital businesses [2].

At present, the production companies must adapt to the changing demands of customers, causing problems at the planning stage of production and material flow logistics. Internal information systems often cannot predict the exact needs and utilization of personnel, inventory, number of vehicles, the floor space required and other parameters if there is a change in conditions. From the perspective of the company it is due to the need to have a planning tool which takes into account changes and provide outputs that indicate how he should behave logistics system [3].

In the background are developed planning tool consumption standards work time analysis or other studies. The task is to define the user input parameters, eg. production program, batch size, etc., and will result in the desired outcomes (eg. the need and utilization of personnel, shift calendar, ...) [4,5].

2. SOFTWARE TECNOMATIX PLANT SIMULATION

Plant Simulation is one from among the available software tools for logistics, developed by Siemens PLM Software for modeling, simulation, analysis, visualization and optimization of production systems and processes, material flow and logistics operations. Using Tecnomatix Plant Simulation, users can optimize material flow, use of resources and logistics for all levels of planning production facilities. This software tool allows a comparison of complex production alternatives, including process logic, computer simulation [6]. It is used for simulation of production and logistics systems. It contains a large number of specialized modules. Field of simulation software developed by Plant Simulation:

- Simulation of logistics activities,
- Simulation of human resources,
- Simulation of production and assembly processes.

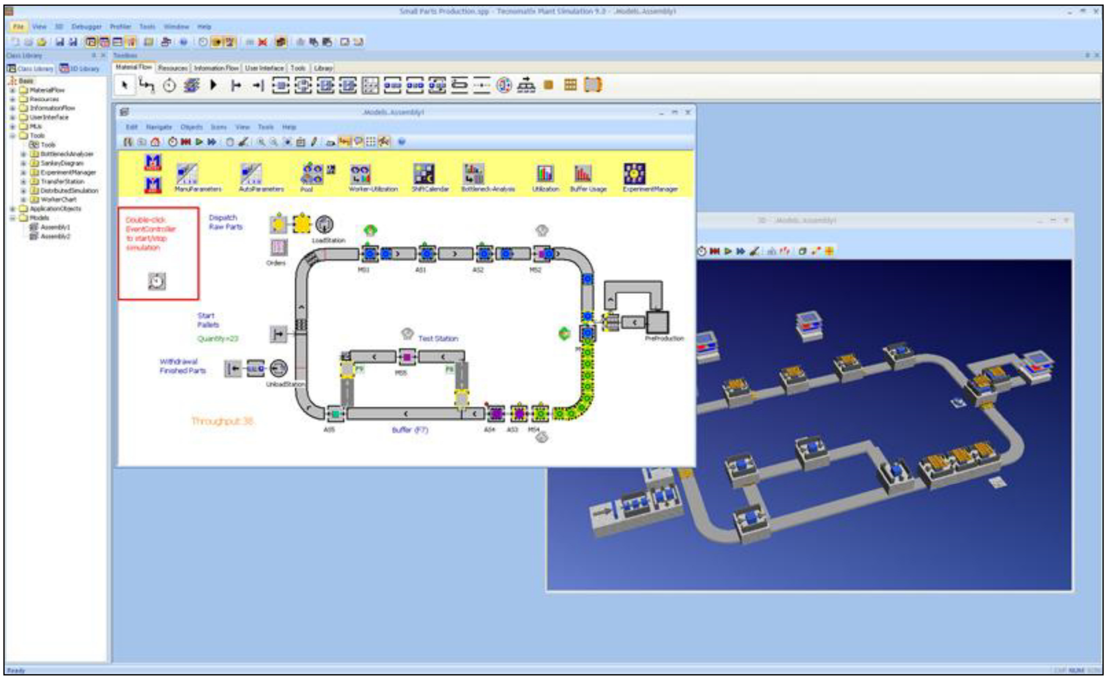


Figure 1 – Example graphical environment Tecnomatix Plant Simulation [1]

2.1. Simulation of logistics – Transportation and warehousing

The advantage of the dynamic simulation modeling and implementation dynamics in the proposed static activity. Observation of movement is important in the transport of material and in both senses, whether internal or external transport. Plant Simulation enables simulation model to assemble logistics systems and internal or external dynamic systems check before putting the system into operation. The use may be in the following fields [7–10]:

- testing of different systems of delivery of goods (direct supply to demand filling circuits, etc.) and their evaluation,
- testing changes the types of transport facilities and their capacity to the system,
- testing of changes in the priorities of transport tasks in the system's ability to provide the required products,
- testing of changes in the system of transport and their impact on production / assembly systems,
- the impact of shift work on-site at different parts of the production / assembly / logistics system to the maximum level stores.

3. MODEL IN THE PROGRAM SORTING LINE TECNOMATIX PLANT SIMULATION MODEL IN THE PROGRAMME SORTING LINE TECNOMATIX PLANT SIMULATION

3.1. Function Description sorting line

To verify the possibility of analysis of logistics processes in Tecnomatix Plant Simulation model was created a sorting line. Sorting lines are nowadays widely used in various industries. Created simulation model is intended for sorting waste according to the scheme Figure 2.

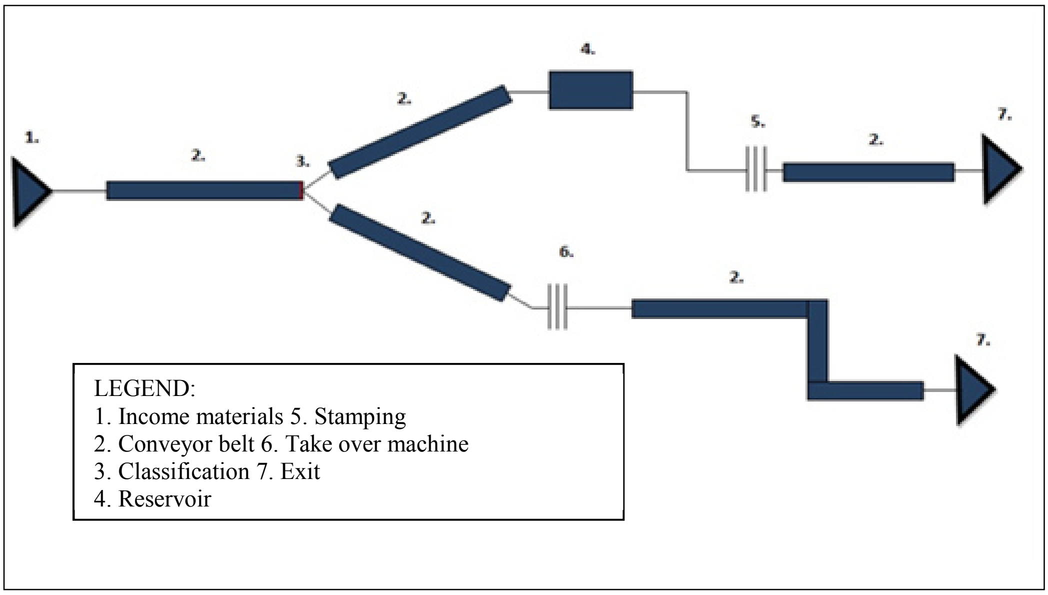


Figure 2 – Scheme sorting line [1]

After receipt of the waste, the said waste spills onto the conveyor, which reaches the sensor. Using the method (Figure 3) is set alternate allocation in sorting packages for two different directions. Municipal waste on line 1 and hazardous waste at the end of Line 2. Line 2 is a machine that can pick up and move the package to another conveyor and continue to the next activity. Tray on top of a tree – a position no. 4 is used for temporary storage of sorted materials. Subsequently, the posted worker who takes over the package garbage and pressing moves it to the garbage – a position no. 5 because of the reduction of storage space. Waste then continues along the conveyor to the other work activities. Acceptance machine, position no. 6, was used due to the hazardous waste. Output at position no. 7 simulation model serves as a warehouse, but also it can be used as a terminal station.

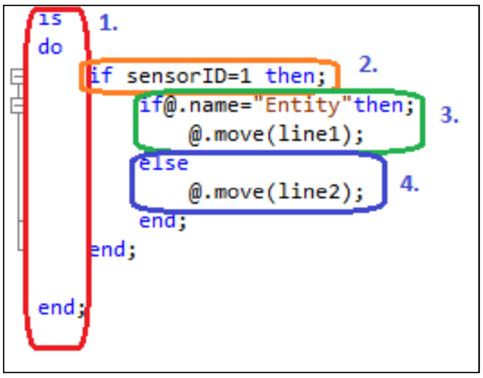


Figure 3 – Example of use sorting methods [1]

3.2. 2D simulation model sorting line and 3D visualization

The simulation begins with object "source" – receiving unsorted material. The model is a truck that will bring the material to the processing plant. Subsequently, at set intervals to the feed conveyor. Set were two types of packages – municipal and hazardous waste, which is color resolution. As a tray on top of a tree was used "buffer" with the set capacity. V upper run at the end of the process output was used as object "Store". In the lower branch of the end of the output was used as object "drain".

Within the simulation model it is also considered the impact of human error. Use the Worker Pool simulates the operation of operators providing the operator sorting line. Thanks gomu can monitor the performance of individual employees and subsequently also evaluated.

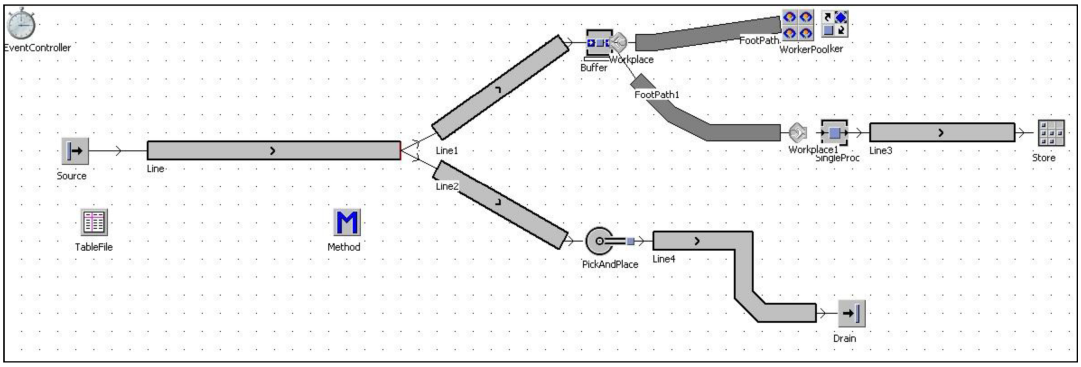


Figure 4 – 2D simulation model sorting line

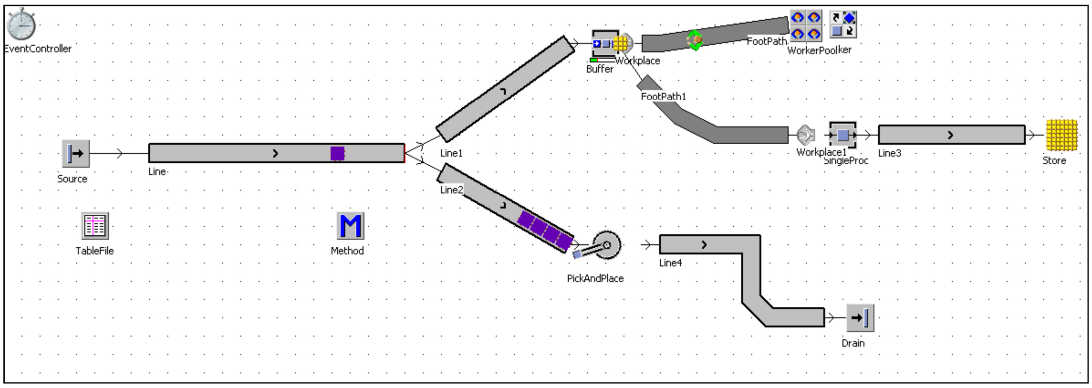


Figure 5 – 2D simulation model sorting line after running [1]

To better understand the operation of the process was performed and the overall visualization in 3D using standard tools Tecnomatix program, which is presented in Figure 6.

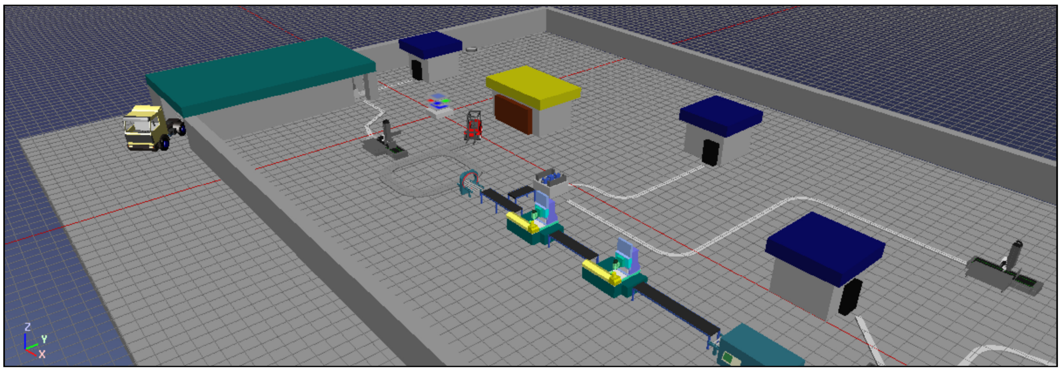


Figure 6 – Example 3D simulation model sorting line [1]

3.3. The usage of the simulation model

Presented simulation model has broad application. It can be used to collect different types of information for analysis during the different activities. Another important possibility of applying simulation model validation and verification of various changes within the real operation and overall optimization of individual activities. It can be used to verify the capacity of and support decision-making processes. The company is also useful such a model at a time when the company going to change especially in expanding production. Company using such models can potentially change without large financial investments to simulate and determine whether it will be this extension of production effective or not. Using models can determine how many workers will be needed to hire or storage capacity currently to satisfy the expansion of production, or what will be the return on investment.

4. CONCLUSION

Analysis of any logistics process is very difficult. This requires detailed knowledge of the good, the use of appropriate methodologies and tools. Among the currently most used methods for the analysis of logistics processes include methods of computer simulation. For its implementation it is possible to use a broad portfolio of simulation software. It should be borne in mind, however, that not all the simulation software are suitable for use in logistics [11]. Among the most useful programs now include software Tecnomatix Plant Simulaion. Using that software can analyze any logistics processes to the smallest detail, then implement their evaluation and optimization.

5. REFERENCES

[1] http://www.innov8.sk/plant-simulation/

[2] EMANS: *Trendy a budúcnosť priemyselných podnikov*, https://www.anasoft.com/emans/sk/home/Novinky-blog/blog/Trendy-a-buducnost-priemyselnych-podnikov, 2016-03-06.

[3] Rak, J. et al.: *The Simulation of Transport Accident with the Leakage of a Hazardous Chemical for Education in Security Forces´ Training*, Proceedings of the 19th International Scientific Conference Transport Means, Kaunas University of Technology, Kaunas, Latvia 2015, 317–320.

[4] INNOV8: *Tvorba plánovacích nástrojov v oblasti logistiky*, http://www.innov8.sk/tvorba-planovacich-nastrojov-v-logistike, 2015-11-21

[5] Molnár, V.: SAP warehouse management system for a warehouse of auxiliary material in the selected company. In: Carpathian Logist. Congr., TANGER LTD. Ostrava.

[6] Fedorko G., Čujan Z.: *Simulation of Procedure for Processing of Consignments in Delivery Company. Switzerland*, Applied Mechanics and Materials : LOGI 2015, Switzerland, Trans Tech publications 803 (2015), 136–141.

[7] Katedra Priemyselného Inžinierstva, *Plant Simulation*, http://www.priemyselneinzinierstvo.sk/?page_id=1695, 2014-10-23.

[8] Fedorko, G., Čujan Z.: *Optimization in modern business practice*, in: Int. Conf. Ind. Logist. ICIL 2014 – Conf. Proc., Faculty of Mechanical Engineering and Naval Architecture, 2014, 167–175.

[9] Fedorko, G., Husáková N., Dudáš G.: *Design of allocation of new technological equipment within the frame of production process in company Getrag Ford Transmissions Slovakia, s.r.o.*, Acta Montan. Slovaca. 15 (2010), 14–22. Available on-line: http://actamont.tuke.sk/pdf/2010/s1/4fedorko.pdf.

[10] Fedorko, G., Rosová A., Molnár V.: *The application of computer simulation in solving traffic problems in the urban traffic management in Slovakia*, Theor. Empir. Res.

[11] Fedorko, G. et al.: *Development of simulation model for light-controlled road junction in the program Technomatix Plant Simulation*, Proceedings of the 19th International Scientific Conference Transport Means, Kaunas University of Technology, Kaunas, Latvia 2015, 694–697.

TIME-BASED COMPETITION: A CASE STUDY OF A BRAZILIAN COMPANY OPERATING IN THE OIL AND GAS INDUSTRY

Ramon Baptista NARCIZO[1], Alberto G. CANEN[2], Iara TAMMELA[1]

[1]Fluminense Federal University, Department of Engineering
Rua Recife S/N, Jardim Bela Vista, Rio das Ostras – RJ,
Brazil
[2]COPPE/Federal University of Rio de Janeiro
P.O. Box 68507, Rio de Janeiro, 21941-972 – RJ,
Brazil

Abstract:

This article presents a study conducted in a Brazilian company that provides containers and logistics equipment to the oil industry. The aim is to analyse practical feasibility of the tools and strategies advocated by a management strategy known as "Time-Based Competition" (TBC) five years after its implementation. The benefits associated with reduced total cycle time as well as process improvements are presented through the application of TBC practices. However, despite some positive results, the company's market share declined. The possible causes of this situation are briefly analysed and contextualized from endogenous and exogenous perspectives.

Keywords:

Time-Based Competition, cycle time, case study, services, oil & gas, Brazil

1. INTRODUCTION

In Brazil, about 85% of oil production takes place offshore, primarily on the northern coast of Rio de Janeiro State, as can be seen in red in Figure 1, and it is supported by an extensive and diverse supply chain [1]. Since transport has become an integrated part of production and distribution systems in this industry, the rental of containers to offshore service providers is among the necessary support services. Competition in this market is high, as a container is an important commodity; therefore, rental price and delivery time are critical factors for clients. Thus, fast customer product delivery is a distinguishing competitive factor for container rental companies [2,3].

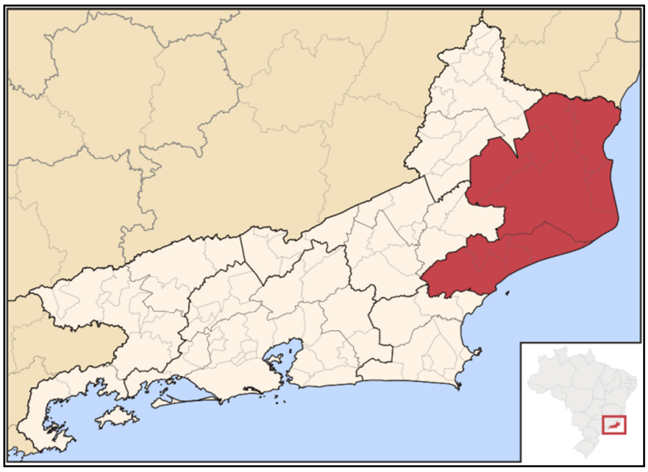


Figure 1 – Rio de Janeiro's State Northern Region. Source: [4]

Customers placed in a competitive environment are becoming increasingly demanding and sensitive to business responsiveness of both manufacturing and services sectors [5]. These authors claim that Time-Based Competition (TBC) is a strategy that combines responses to customer needs for the rapid introduction of new products with both high quality and low costs by reducing the total cycle time. TBC demands a high degree of commitment to challenge the existing methods and examine all processes thoroughly and cautiously [6]. These results can only be achieved by the compression of time between each stage of the process, from creation to distribution [7]. The logic of TBC poses a direct challenge to traditional cost reduction efforts, such as shortening of operations and increasing the use of equipment, showing that currently competitive success in various industries depends on a relentless compression of time – not just costs - of research and development, production and logistics [6,8,9].

The purpose of this paper is to present the results achieved five years after the implementation of TBC's practices and strategies in a company dedicated to the rental of containers and metal packaging for maritime transport. The study began in 2009, when an academic research project was implemented in the studied company, a firm established in the northern region of the Rio de Janeiro State (Brazil), operating in the chain of service providers to the exploration and production of oil and natural gas. The maintenance sector, divided into two macro-phases, repairs in the metal structure and painting of containers, was the main process addressed in the project. The main purpose was to demonstrate the feasibility of implementing TBC as a competitive strategy by reducing cycle time in the maintenance process.

In terms of structure, the article first presents a brief review of the literature about the TBC, focusing on the relationship between the reduction of total cycle time and gain of sustainable competitiveness. The basic methodology used to carry out this study was exploratory research and semi-structured interviews with the staff, managers and senior management. Research has shown that the company has achieved performance gains, demonstrating the relevance and feasibility of TBC as a competitive strategy. However, despite some positive results, the company had its market share reduced. Possible causes of this situation are briefly analysed and contextualized from endogenous and exogenous perspectives. This research is relevant because in a competitive and globalized market, studies on improving time management and competitiveness gains are increasingly necessary.

2. TIME-BASED COMPETITION

The concept of Time-Based Competition was first introduced by [10] to point out that time is a more important competitive factor compared to traditional ones [9]. The goal of companies competing on time, according to [11], is to achieve a sustainable competitive advantage. Therefore, for the main competitors, time has become the primary measure of performance, using indicators such as new product introduction time, production lead-time, and delivery speed [12]. As described by [13], TBC can be seen as a strategy to develop a sustainable competitive advantage, leading to reduction in cycle-time in both make-to-stock and make-to-order industries. As claimed by [14], competition based on time involves not only a simple compliance with delivery dates, but also careful management of time, treating it as a limited resource while continuously removing waste and activities that do not add value.

Companies can follow several strategies and practices to become competitors based on time, reducing the total cycle time of its operational activities. According to [15], the implementation of TBC follows seven fundamental strategies: 1) system simplification; 2) system integration; 3) standardization; 4) introduction of parallel activities; 5) variance control; 6) automatization; and 7) diminishing resources excess. These strategies deal with the lead-time problems of product development, manufacturing, and logistics distribution.

The problem is to choose and determine the best strategy to meet the needs and goals of each company [16]. As stated by [17], the total cycle time of a business can be measured by the time elapsed between the identification of customer's needs and the delivery of the solution. The total cycle time comprises several sub-cycles, such as manufacturing, distribution, supplying, storage, materials management, and business development strategy [18]. Accordingly, [19] argued that most of the time spent in total cycle is a sum of various delays among steps rather than the proper product manufacturing time. This suggests that reducing existing inefficiencies in orders' transmission, processing, and delivery time constitutes a competitive advantage.

As stated by [20], companies that use Time-Based Competition have several things in common, such as reduced total cycle time; reduced market response time; shorter time for development and introduction of new products; less time between an order and delivery of a product or service; reduction of non-value-added time to the systems, either in manufacturing or in the service industry; flexibility; and speed. The importance of good logistics practices and partnerships with suppliers is also highlighted [11,16]. Any company, regardless of its size or type, can obtain this advantage by meeting the needs and expectations of consumers, leading to better products and services, faster compared to competitors. Thus, time appears as a solution to the search for leadership [2,6].

3. CASE STUDY

The organization under study, as already mentioned, is a mixed capital firm founded in 2000 and dedicated to renting containers and other equipment to local oil and gas service providers. TBC has been identified as a possible competitive mechanism for this company because with respect to the maintenance, a container only starts in this process after the customer has already rented it, similar to a Just-In-Time production logic.

The studied company needs to make its products available faster and cheaper compared to local competitors. Although the market for containers rental in the region is relatively stable, with a high level of demand throughout the entire year, time is a critical success factor. Since the product is a commodity, and customers are not willing to pay more for speed, competition comes down to faster deliveries with lower prices.

Figure 2 – Three types of major equipment. Source: Company X

In the 2009-2014 period, the company presented a wide range of equipment available for rental, but three categories stood out in terms of turnover: metal boxes (various sizes), 20' containers (6.06m in length, 2.44m wide and 2.59m high), and 10' containers (3.03m in length, 2.44m wide and 2.59m high). Examples of these products are shown, in that order, in Figure 2. These three products accounted for, on average, about 42% of the equipment that the company has made available for rental during these five years. Revenue from renting such products represented more than 50% of total company revenues in the period. Other products the company offered were weatherproof panels, tubular scaffolding, metal baskets, metal skids, compressors, air distributors, and generators. More information about the most representative equipment is seen in Table 1.

Table 1 – Most representative products

PRODUCT	PERCENTAGE OF TOTAL EQUIPMENT	
	2009	**2014**
Metal boxes	16.0	16.9
Container 10'	9.6	8.8
Container 20'	19.8	12.3
Others	54.6	62.0
TOTAL (%)	**100.0**	**100.0**

Considering the representativeness of metal boxes, 20' and 10' containers to the company's business, the study focused on getting results on maintenance time for these equipment. To achieve this, when the study began in 2009, we defined two basic assumptions. First, we proposed that using the strategies provided by TBC, the operations management of these three products lines would improve through obtaining productivity gains, reductions in cycle time, reworking and costs for a production share, which represents more than half of the sources of the entire organization's revenue. The second assumption was that the equipment mentioned above, due to high demand all year round, inevitably ends up generating bottlenecks in the maintenance sector. Although the company focuses on rental activities, through a mapping of processes and value chain analysis, the role of maintenance process emerged as the major candidate to reduce cycle time. The main problems found related to product repair and painting.

Product repair (metalwork): Maintenance process begins with a visual inspection of the product's metal structure, and three diagnoses were possible, bad conditions, i.e., with many repairs to be made; good conditions (only minor repairs needed); and optimal conditions, i.e., repair services not needed, so the item can be delivered directly to painting. This sector had the highest number of bottlenecks. The research raised the following issues:

Reworking: Visual inspections failures caused sending the containers to painting sector when they should have been sent to repair.

Inadequate positioning of inventory: Stocks and raw materials located too far from the workplace caused imbalance between needs and delivery of materials.

High waiting times: Due to technical limitations, electro-mechanical and pneumatic equipment could not operate simultaneously, causing loss of performance, delays, high cycle time and increasing costs.

Product painting: The painting sector followed a more standardized flow compared to product repair. While the metal department needed to analyse and inspect the equipment, deciding what types of maintenance services would be needed, the painting sector always received the products in the same conditions in need of the same type of work. This enabled a more constant workflow easily predictable over time. Research in this sector raised only one issue:

High waiting times: Due to the space and security constraints, the painting was performed using brushes and rollers. This was because painting and repair shared the same physical space. Moreover, room for painting was not appropriate, leading to long delays before drying the product so it could be removed for the clearance area.

The bottlenecks identified in the repair sector are common in this type of industry in Brazil. With regard to reworking, TBC points to several strategic mechanisms that can reduce it dramatically, such as mapping and improvement of processes to ensure the elimination of activities that do not add value to the customer, creating an organizational environment that fosters continuous learning, and introducing cross-functional teams to improve decision-making and reduce bureaucracy.

Table 2 – Product repair average time

EQUIPMENT			REPAIRS (METAL WORK)							
Conservation state	Percentage of total		Average time (hours)							
			Bottom		Sides		Ceiling		TOTAL	
	2009	2014	2009	2014	2009	2014	2009	2014	2009	20014
Bad	10	67	7.5	3.8	9.5	4.8	5.0	2.5	22.0	11.1
Good	80	33	4.0	2.9	3.5	2.5	2.5	1.8	10.0	7.2
Optimal	10	0	(*No metal work or repair needed, straight to painting*)							

Considering the theoretical framework underlying the TBC along with the interviews conducted with the staff, managers and senior managers, some measures to reduce total cycle time are outlined. Regarding repairs, the following changes were made: introduction of cross-functional teams to handle inspection and diagnosis of problems and implementation of a resource management system for materials. These changes reduced about 50% of total repair time for products in good condition and 38% for products in bad state, as shown in Table 2.

Table 3 – Product painting average time

PAINTING ACTIVITY	DURATION (HOURS)	
	2009	2014
1A. Application: Bottom (external)	1.5	1.0
1B. Drying: Bottom (external)	1.0	0.8
2A. Application: Side, bottom (internal) and door	1.5	1.0
2B. Drying: Side, bottom (internal) and door	In parallel	In parallel
3A. Application: Internal walls	In parallel	In parallel
3B. Drying: Internal walls	2.5	2.0
4A. Finishing	In parallel	In parallel
4B. Drying: Finishing	1.5	1.2
TOTAL (HOURS)	8.0	6.0

Addressing the company's internal environment, the introduction of TBC practices in painting activities provided up to 25% reductions in time, as showed in Table 3. As it can be seen in Table 4, after the introduction of TBC as a competitive strategy, equipment in bad condition went from consuming 28 hours to 17.1 hours to receive the full maintenance (repairs and painting) while a container in good condition went from consuming 16 hours to 13.2 hours. However, we observed that the maintenance sector, even after five years of practicing TBC strategies, is not yet fully organized, lacking a greater formalization and support structure.

Table 4 – Comparing times in maintenance sector (2009 versus 2014)

CONSERVATION STATE	MAINTENANCE TIME (HOURS)					
	Repair		Painting		TOTAL	
	2009	2014	2009	2014	2009	2014
Bad	22.0	11.1	8.0	6.0	28.0	17.1
Good	10.0	7.2	8.0	6.0	16.0	13.2
Optimal	-	-	8.0	6.0	8.0	6.0

On the other hand, with respect to the external environment, the region had about 40 companies competing in this market in 2009, most of which were small businesses. In 2014, only 11 companies, which were responsible for about 90% of local market volume, still operated in the sector, including the studied company characterized as a medium to large enterprise. In comparison, about 4,000 containers were available for rental in 2009, and the case study company had around 900 containers for rental, an estimated 22% of the market. In 2014, the total number of containers offered in the market was estimated at 30,000 units, and the company in the study had 2,254 equipment, allowing us to estimate its market share at about 8%.

4. CONCLUSIONS

This study aimed to verify the feasibility of applying TBC strategies to gain sustainable competitive advantage against competitors. We showed that the company achieved reductions in cycle time for the maintenance process. However, we understand that these results, although positive, do not represent the performance gains expected when TBC was proposed as a competitive strategy for the case study company back in 2009.

The study also showed that the company lost much of the market share it had in 2009. However, the market as a whole showed a significant growth in five years. Small businesses that operated in the container rental industry went bankrupt, or larger entrants acquired them. The sector also demonstrated maturity and quality gains in management.

Moreover, research has shown that the company in this study did not fully implement TBC, being essentially limited to the maintenance sector. Sectors related to financial and personnel management, for instance, demonstrated resistance to adopt TBC as a strategy for the entire company. However, this article presents some limitations, mainly in the level and extensibility of the results, since the research is dealing with two isolated moments of the company under study in time.

Finally, in terms of the conceptual framework of TBC, the paper argues that it cannot be treated as something new or a panacea. That is, this competitive strategy can be understood as a summation of assumptions, concepts, methods, and tools that include aspects from various other competitive strategies related to improving processes and reducing waste and activities that do not add value. We recommend that future studies investigate the application of time-based and logistical strategies in others Brazilian container rental companies to complement the primary investigation presented in this study.

5. REFERENCES

[1] Silvestre, B.S.; Dalcol P.R.T.: *Geographical proximity and innovation: Evidences from the Campos Basin oil & gas industrial agglomeration—Brazil*, Technovation, 29(8)(2009), 546–561.

[2] Demeter, K.: *Time-based competition — the aspect of partner proximity*, Decision Support Systems, 54(4)(2013), 1533–1540.

[3] Pedersen, P.O.: *Freight transport under globalisation and its impact on Africa*, Journal of Transport Geography, 9/2 (2001), 85–99.

[4] Wikipedia: *Mesorregião do Norte Fluminense*, https://goo.gl/fvZMwm, 28-11-2015.

[5] Hum, S.-H.; Sim H.-H.: *Time-based competition: literature review and implications for modeling*, International Journal of Operations & Production Management, 16(1)(1996), 75–90.

[6] Nagurney, A., Yu M., Floden J. Nagurney L.S.: *Supply chain network competition in time-sensitive markets*, Transportation Research Part E: Logistics and Transportation Review, 70(2014), 112–127.

[7] Zairi, M.: *Competition: what does it mean?* The TQM Magazine, 8(1)(1996), 54–59.

[8] Hicks, D.A.: *Time wars: Is there a financial undertow from accelerating technical advance?*, Research-Technology Management, 43(2)(2000), 34–39.

[9] Blackburn, J.: *Valuing time in supply chains: Establishing limits of time-based competition*, Journal of Operations Management, 30(5)(2012), 396–405.

[10] Stalk, G.: *Time-The next source of competitive advantage*, Quality Progress, 22(6)(1988), 61–68.

[11] Tammela, I., Canen A.: *Time-based competition related to logistics: an international study of furniture companies*, Proceedings of ICIL, Rio de Janeiro, March 2010, 45–53.

[12] De Toni, A.; Meneghetti, A.: *Traditional and innovative paths towards time-based competition*, International Journal of Production Economics, 66/3 (2000), 255–268.

[13] Carter, P.L., Melnyk S.A., Handfield R.B.: I*dentifying the basic process strategies for time-based competition*, Production and Inventory Management Journal, 36(1)(1995), 65–75.

[14] Sim, K.L., Curatola A.P.: *Time-based competition*, International Journal of Quality & Reliability Management, 16(7)(1999), 659–674.

[15] Carter, P.L., Melnyk S.A., Handfield R.B.: *Identifying the Basic Strategies for Time-Based Competition,* Production and Inventory Management Journal, First Quarter 36(1)(1995), 65–70.

[16] Tammela, I., Canen A.G., Helo P.: *Time-Based Competition: Relation to multiculturalism and logistics in international furniture companies*, Benchmarking: An International Journal, 20(5)(2013), 588–606.
[17] Meyer, C.: *Fast cycle time: How to align purpose, strategy, and structure for speed*, The Free Press: New York, 1993.
[18] Northey, P., Southway N.: *Cycle time management: the fast track to time-based productivity improvement*, Productivity Press: Boca Raton, 1993.
[19] Ballou, R.H.: *Business Logistics & Supply Chain Management*, Pearson Education: New York, 2007.
[20] Tammela, I.; Canen A.G., Helo, P.: *Time-based competition and multiculturalism: A comparative approach to the Brazilian, Danish and Finnish furniture industries*, Management Decision, 46(3)(2008), 349–364.

SECONDARY AND TERTIARY PACKAGING IMPROVEMENT OPPORTUNITIES INTO LOGISTICS PROCESSES

Pavels PATLINS[1], Remigijs POCS[1]

[1]Faculty of Engineering Economics and Management
Riga Technical University,
1st Kalku Street, Riga,
Latvia

Abstract:

The paper deals with the secondary and tertiary packaging improvement opportunities into logistics processes. It is extremely important to use the optimal packaging today, in other case the quality of the logistics processes may fail. The purpose of the paper is to analyze the importance of the optimal secondary and tertiary package into logistics processes today as well as way how to use the best secondary and tertiary package for logistics processes. Main branches of investigation are warehousing and road transportation processes. The author investigated the influence of the different types of secondary and tertiary package to these processes efficiency. Indeed, package is important also for other logistics processes. The main solution is: standardization of package's sizes. This allows using vehicles and warehouse's space by optimal way, improving the result of logistics processes. The Research is supported by the National Research Program 5.2. EKOSOC – LV.

Keywords:

Secondary Packaging, Tertiary Packaging, Logistics processes, Efficiency, Improvement

1. INTRODUCTION. THE ROLE OF GOODS PACKAGING INTO LOGISTICS PROCESSES

Either manufacturing companies or trading organizations or logistics enterprises understand the significance of goods packaging for the modern entrepreneurship. Actually, the final customer first of all may see package, not product at once. On the on hand, packaging may influence also primary customer choice, so it is very important for marketing, because package should be attractive and good for the customer. Thus working out the package for goods (especially for luxury and top-quality goods) designers and other specialists. On the other hand, logistics aspects of goods packaging also are very important.

The definition of packaging is "a coordinated system of preparing goods for safe, efficient and cost-effective transport, distribution, storage, retailing, consumption and recovery, reuse or disposal combined with maximising consumer value, sales and hence profit", so there ought not to be any doubt of the importance of this system's view when it comes to packaging design and use [1].

Consumers generally buy products in small quantities. They sometimes make purchase decisions based on product looks and packaging. Retailers are deeply concerned to get products that are easy to handle in logistics terms, don't cost too much to package or handle, yet retain their selling ability on shelves. Secondary and transit packaging can be a cost to the supply chain and is increasingly replaced by returnable handling systems where possible. Unitization is combined with standardization to provide order to the handling of products [2].

Packaging is a means of ensuring safe and efficient delivery of the goods in sound condition to the ultimate consumer, supplemented by efficient reuse of the packaging or recovery and/or disposal of the packaging material at minimum cost' [3].

Many managers of logistics and transport companies (e.g. DHL) suppose, thatpackaging of the goodsis a critical factor in logistics. And the reason is clear: without it, many logistics processes could not be performed at all or could be carried out only at great additional cost. The function of the packaging is not just to protect the product. It performs many other jobs as well. These include providing information about the contents as well as enabling and facilitating other logistics processes – including transport and handling as well as storage, order processing and warehousing [4].

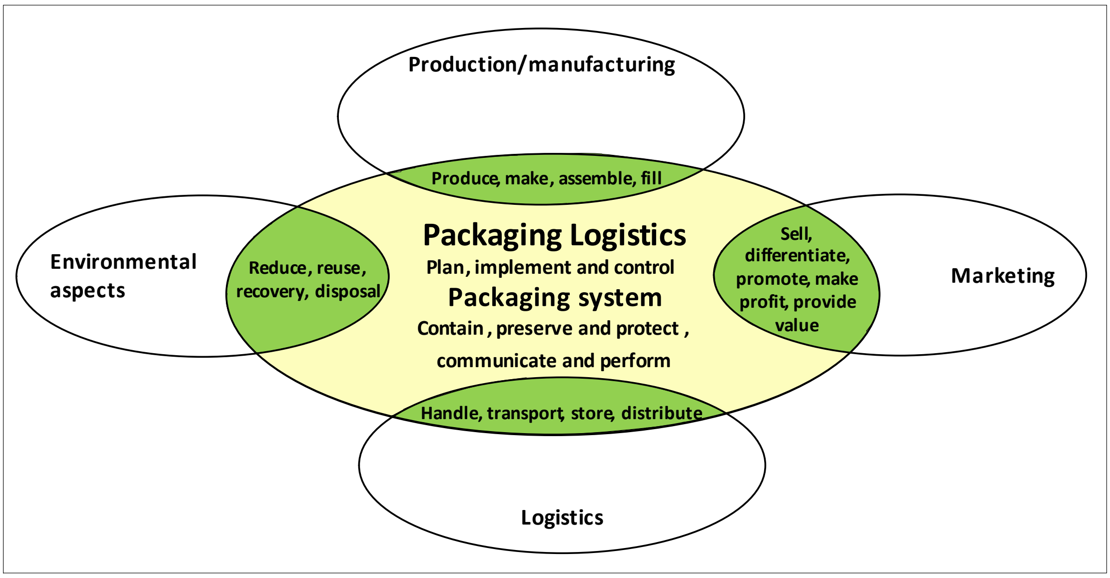


Figure 1 – Packaging logistics relationships [5]

Image 1 illustrates packaging logistics relationships. Certainly, companies have to pay a great attention to manufacturing aspect of packaging, as well as marketing problems, environmental aspects and logistics details.

2. LEVELS AND FUNCTIONS OF GOODS PACKAGE

There are many different classifications of packaging. It is expediently to investigate types of packaging influenced logistics processes and delivery.

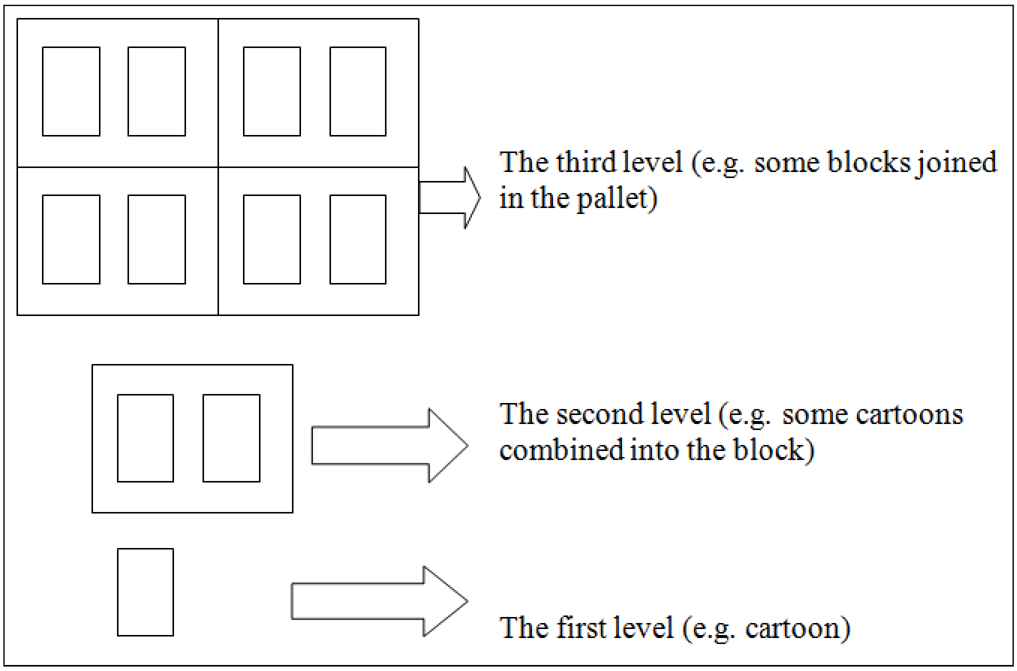


Figure 2 – Levels of good packaging

It is necessary to plan levels of packaging for logistics processes to plan transportation, storage and warehousing as well as other processes (Image 2). Primary packages hold the basic product and are brought home from the shop by the end consumer. Secondary packages, or transport packages, are designed to contain several primary packages. A secondary package could be taken home by the end consumer or be used by retailers as an aid when loading shelves in the store. The third level of packaging, tertiary packages comes into use when a number of primary or secondary packages are assembled as, for example, on a pallet.

Some authors mention following examples of tertiary packaging : stretch films, tension nets or ties for strapping the unit load [6].

There are different logistics functions of the packaging – that is, protection, storage, transport, information and handling.

As a result, the packaging may be regarded only as a part of the entire logistics system. In packaging design, a compromise that addresses all functional areas must be found. The correct design of packaging can help lower overall logistics costs and raise the level of supply and/or delivery service . In addition to the logistics functions, packaging must also fulfill production functions, marketing functions and usage functions. This means:

- through the choice of suitable packaging, it is possible to produce directly from the packaging or into the packaging without intermediary processing procedures.
- packaging can lend a special character to a product, enabling it to be distinguished from the competitors' products. Important functions can also be assigned to packaging, including roles in advertising and sales promotions.
- in light of environmental considerations, it is essential for packaging design to meet these needs. Ideally, the design should make it possible for a customer to recycle the packaging or facilitate its use for other purposes [4].

Packaging is a system for preserving the safety and quality of food products throughout the whole distribution chain to consumer by:

- Maximising shelf life.
- Carrying important information on the label relating to preparation, safety and nutrition.
- Providing evidence that the package is intact and the product has not been tampered with.
- Identifying the date and the location of manufacture for inventory control and identification of potential hazards[7].

So, packaging is very significant logistics support operation.

Despite of the fact that goods' package planning is extremely important problems into logistics processes, a lot of manager do not control this process as well as do not pay enough attention to package planning and design.

The author will analyze the problems connected with the secondary and (mainly) tertiary package.

3. SECONDARY AND TERTIARY PACKAGING IMPROVEMENT OPPORTUNITIES INTO LOGISTICS PROCESSES

3.1. Problem's description

A lot of retailing companies have various problems connecting with secondary and tertiary package into logistics processes. Often the main problem is that package takes too much place, making the transportation process absolutely inefficient and expensive.

The authors analyzed particular companies' deliveries for 2 weeks and assumed information about their package problems into logistics processes as well as made out ways how to solve these problems.

Table 1 gives a random sample of investigated companies' delivery analysis.

Table 1 – Cargo net and gross volume (paper's authors' investigation information)

Number of customers	Cargo net volume m^3	Average cargo net volume per customer, m^3	Average cargo gross volume per customer, m^3	Cargo gross volume, m^3
76	5.19	0.068	0.136	10.336
145	23.11	0.159	0.318	46.11

Pallet capacity useful usage rate may calculate using formula 1:

$$PCU = H \cdot A \cdot \frac{NCV}{CGV} \quad (1)$$

where:
PCU – Pallet capacity useful usage rate;
H – height of cargo, m;
A – area of the pallet, m2;
CNV –cargo net volume, m3;
CGV – cargo gross volume,m3;

The corner-stone problem of various retailing companies is that PCU often takes only around 50% of the CGV. Usually H=1.5 m; A= 1.2*0.8 – 0.96 m2 (euro pallet).As a result, net cargo takes only one half of the total cargo volume. The second half is package (carton of bubble wrap). Very often companies put only some pieces of packaged goods into tertiary package; filled reminding space with carton of bubble wrap.

In this case it is impossible to load net volume cargo 23 m3 into standard 13.8 m lengthtruck.

3.2. Solution. Tertiary package optimization for transportation

Companies have to use additional vehicles as a result transportation costs growth. It is expedient to use standard size cartoons, loading them full to make cheaper transportation process.

Cartoon size 0,4x0,5x0,25 m is quite popular now. It is necessary to fulfill them with product into packaged into primary package, taking into account fact, that often primary package has a shape of ellipse or sphere.

Using this principle, it is possible to use maximally tertiary package space (Table 2).

Table 2 – Package solution using standard-size cartoons

Number of customers	Cargo net volume m^3	Cargo net volume to one customer, m3	Cartoon 0,4x0,5x0,25 m	Number of cartoons to one customer	Cargo gross volume, m^3
76	5.19	0.068	0.05	1.36 (2)	7.6
145	23.11	0.159	0.05	3.18 (4)	29

Analyzing table 1and table 2 information, may conclude that cargo gross volume decreases per 27% for the first variant (76 customers) – from 10.3 m3 to 7.6 m3 and per 37% (from 46.11 m3 to 29 m3). Of course this principle allows reducing of transportation costs too.

The fifth column of the table 2 provides information, that the last cartoon is not fulfilled. (36% and 18% for both variants). In this case it would be expedient to use 2 types of standard cartoons – before mentioned size 0.4x0.5x0.25 m as well as half size of this cartoon.

Theses ways of package optimization allows to reduce also used pallets quantity, saving net volume of cargo, reducing total delivery costs. Table 3 demonstrates pallets quantity decrease for nine deliveries.

Calculating differences between package systems before and after optimization may compute also transportation costs and companies' benefit using optimized packaging system.
Baltic States companies often purchase production from Poland (Warsaw) distributing companies. The table 4 provides information about cargo delivery costs between Warsaw and Riga for different amount of cargo.

Table 3 – Pallets quantity needed for delivery using different package methods (paper's authors' investigation information)

Date	Package system before optimization				Package system after optimization		
	Number of customers	Cargo net volume m^3	Cargo volume on 1 pallet, m^3	Quantity of pallets	Cargo net volume to one customer m^3	Cartoon quantity to each customer, using standard size cartoons	Quantity of pallets
2016.05.29	6	4.11	0.72	6	0.685	14	3
2016.06.01	145	23.11	0.72	33	0.159	4	19
2016.06.17	15	1	0.72	2	0.067	2	1
2016.06.18	76	5.19	0.72	8	0.068	2	5
2016.06.19	1	0.21	0.72	1	0.21	5	1
2016.06.05	7	0.54	0.72	1	0.077	2	1
2016.06.08	59	6.2	0.72	9	0.105	3	6
2016.06.12	179	12.87	0.72	18	0.072	2	12
2016.06.15	4	0.34	0.72	1	0.085	2	1

Table 4 – Delivery costs between Warsaw and Riga for 1–10+ euro pallets (paper's authors' investigation information)

Euro pallets (0.8x1.2m)	1	2	3	4	5	6	7	8	9	10	+1
Delivery Price, EUR	62	97	131	158	172	193	206	240	272	285	15

Investigating information from table 4, may calculate total benefit for transportation and logistics process for companies which use optimized tertiary package system (table 5).

Table 5 – Delivery costs benefit using optimized tertiary package system

Number of customers	**Cargo Net volume, m3**	**Quantity of pallets (Before changes)**	**Delivery costs(EUR)**	**Quantity of pallets (after optimization)**	**Delivery costs(EUR)**	**Differences of delivery costs (EUR)**
6	4.11	6	193	3	131	62
145	23.11	33	630	19	420	210
15	1	2	97	1	62	35
76	5.19	8	240	5	172	68
1	0.21	1	62	1	62	0
7	0.54	1	62	1	62	0
59	6.2	9	272	6	193	79
179	12.87	18	405	12	315	90
4	0.34	1	62	1	62	0
SUM			2023		1479	544

PCU rate may increases from 50% to 80-90%. Total delivery cost in the given example is 2023 EUR before the tertiary package optimization. After the package system change, the costs reduced per 544 EUR and achieved 1474 EUR. The given example investigates period of tome around 2 weeks; so companies benefit per year would be greater (around 15000 EUR).

This approach is quite simple and very useful for real business practice when companies' managers do not pay enough attention to problems connected with cargo secondary or tertiary packaging.

4. CONCLUSION

Despite of the fact that goods' package planning is extremely important problems into logistics processes, a lot of manager do not control this process as well as do not pay enough attention to package planning and design.

Packaging problem is especially difficult for goods with special shape of primary package. In this case special approaches needed to optimize tertiary packaging and improve logistics process. Control and optimization of tertiary package allows improving of the logistics process as well as providing of benefit to companies, reducing transportation and logistics costs.

It is expedient to use standard-size cartoons for tertiary package optimization. Companies have to choose 1 or 2 most suitable size of cartoons and use it to serve customers by optimal way, simultaneously reducing transportation costs.

5. REFERENCES

[1] Paine, F.: *Packaging Design and Performance,* PIRA International, Surrey, UK 1990.

[2] Johnsson, M.: *Packaging logistics – a value added approach*, PhD dissertation, Lund University, Lund, Sweden, 1998.

[3] Jönson, G. Johnsson, M.: *Packaging logistics in product development*, 5th International Conference on Computer Integrated Manufacturing, ICCIM 2000.

[4] http://www.dhl-discoverlogistics.com/cms/en/course/tasks _functions/packaging /functions.jsp . Functions of packaging, 02-07-2012.

[5] Saghir, M.: *A platform for packaging logistics development – a systems approach,* Doctoral dissertation, Department of Design Sciences, Lund University, Lund, Sweden 2004.

[6] Gustafsson, K., Jönson G., Smith D., Sparks L.: *Retailing Logistics &Fresh FoodPackaging*, Kogan Page Limited, London 2009.

[7] Position Paper packaging and food safety, World Packaging Organization, 2008.

[8] Patlins, P.: *Road transportation planning optimization within logistic system*, Doctoral dissertation, Riga Technical University, Riga, Latvia 2011.

[9] Patlins, P.: *Universal Routing Algorithm for Cities and Other Built-Up Areas*. In: Zadnik Stirn, Drobne, Nemec (Eds.). 8th International Symposium on Operational Research in Slovenia, Nova Gorica, Slovenia,SOR'05 proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2005.

THE USE OF AHP METHOD TO SELECT OPTIMUM MEANS OF TRANSPORT FOR STRATEGIC GOODS

Jacek RYCZYŃSKI[1], Paulina KRAWCZYSZYN[1]

[1]Tadeusz Kosciuszko Military Academy of Land Forces
Czajkowskiego 109, Wroclaw
Poland

Abstract:

It is well known that transport is significant part of human life. The article presents usage of the Analytic Hierarchy Process (AHP) to optimize the method of choosing specific airplane to transport strategic goods. Usually, the mean of transport for that kind of cargo is selected by specialists but simple decision-making method like AHP could be solution for those who has no experience in that matter. The result of the article shows, that the Analytic Hierarchy Process method could be used as a support in choosing proper mean of transport or model of the vehicle, but it obviously cannot replace the specialists knowledge.

Keywords:

AHP method, air transport, strategic goods

1. INTRODUCTION

Decision-making processes often caused many problems to those who are responsible for taking the decision. Therefore simple methods to support may facilitate decision-making to persons who do not have sufficient experience. The aim of this article is to present the methods of AHP to select the optimal means of transport during carriage of goods strategic. Method AHP consists of decomposing formulated the problem into simpler components and processing the expert evaluations on the basis of the comparison in pairs. Modelling using hierarchical fault analysis AHP is useful especially when is not known relationship between the functional elements of the problem of decision-making, described in the form of a hierarchy of factors, while it is possible to estimate the effect of data ownership and their practical effect. In this article has been presented method AHP and practical example of the use of these tools in solving the problem multicriterial air transport strategic materials in the district affected by the war.

2. AHP METHOD

The method of Analytic Hierarchy Process (AHP) was created by Thomas L. Saaty from the University of Pittsburgh in the 1970s. AHP is a general hierarchical approach to take multicriterial decision, which lets you connect criteria quantified with non–quantified and objectively measurable with subjective. Thanks to the AHP can be optimal choices when dealing with more than one selection criterion by summary of comparisons in pairs. Summary of the most commonly do with experts so you can compare the criteria objectively measurable with subjective memory [1]. AHP is about the distribution of the problem of the decision-making on the simpler components and then comparison in pairs on the basis of expert assessment. The Analytical Hierarchy Process consists of four stages:

1. Prioritize the issue – the goal of this step is a detailed description of the problem and identification of the participants, the determination of the primary objective and the expectations in relation to it. Then shall be decomposition problem in the form to the parent of the main factors and factors involved and concerned variants that generate some degree of fulfilment of the objectives of the different levels of the hierarchical design model.

2. Comparison of pairs – quantitative and qualitative criteria comparison with the same level in the context of the parent; makes the decision–maker, which compares with each other in pairs in relation to the criteria, and the criteria in relation to the parent on the basis of a subjective determination that the criteria and the extent to which is more important than the other. Relations between the elements is determined on the basis of the nine–scale:
   - 1 – equal significance;
   - 3 – a small advantage;
   - 5 – a strong advantage;
   - 7 – very strong advantage;
   - 9 – absolute advantage;
   - 2, 4, 6, 8 – intermediate values
3. Determine the weights of the various criteria – after the construction of the array is calculating weights criterion. Are summarized standardized rows and the array is calculated vector own array. A common situation is the situation where the assessment from experts are not always completely objective, so enter the inconsistencies.
4. Assessment of objects – select the best option that best fits the parent.

It should be noted that the method of AHP has several advantages. The most important replace that problem is presented in the form of a simple hierarchical model so that it is easy to understand and will be used in the consideration of a wide range of problems. A second important feature of the AHP is able to take into account the factors both measurable and not measurable. Thanks to its assets, Analytical Hierarchical Process is used in many areas. For both the assessment of credit [3,4], estimating safety technical object, and in the field of transport.

3. THE STRATEGIC GOODS AS A SPECIAL CASE LOADS

Among the many factors affecting transport can include weather conditions, or the reliability of the means of transport. The element unifying all these factors is safety. It is particularly important when you are transported for example: strategic goods. According to the law on foreign trade in goods, technologies and services of strategic importance for national security and for the maintenance of international peace and security, strategic goods are armaments and military equipment and dual–use items. Definition of the first group falling in strategic goods is not needed. In contrast, through the dual–use items shall mean products including software and technology, which can be used for both civilian and military purposes, and shall include all goods which can be used for both non–explosive uses and in any way to support the manufacture of nuclear weapons or other nuclear explosive devices [2,3,5].

3.1. The example of the use of methods of AHP to select the optimal aircraft for the transport of strategic goods

To modeling decision-making situation for article, selected loads are three pallets from a strategic with a total mass of 9 tones, which has to be transported from Wroclaw to Kabul. The length of the route is approximately 5000 km assuming that the airplane for safety reasons will not was flying in a straight line to bypass the zone of third failed, such as Ukraine and Syria. The analysis have been selected three transport aircraft with comparable parameters which are used for military strategic transports. In Table 1 were presented the selected technical data of aircrafts.

Table 1 – Summary of the technical specifications of your choice of three models of aircraft

Airplane	Load Capacity	Range	Cruising speed
C-130 Hercules	20 400 kg	3 800 km	592 km/h
C-27J SPARTAN	11 500 kg	1 852 km	583 km/h
C-295 Chaff CASA	9 250 kg	3700 km (load 6 000 kg)	576 km/h

The problem of the choice of the optimal aircraft is shown in Figure 1. The main objective of the analysis is the best mix of aircraft for the transport of strategic goods on the Wroclaw to Kabul, taking into account the established criteria. Were adopted three criteria: capacity, the range and cruising speed. In the example under consideration was also adopted three variants of the solution to the problem in the form of aircrafts.

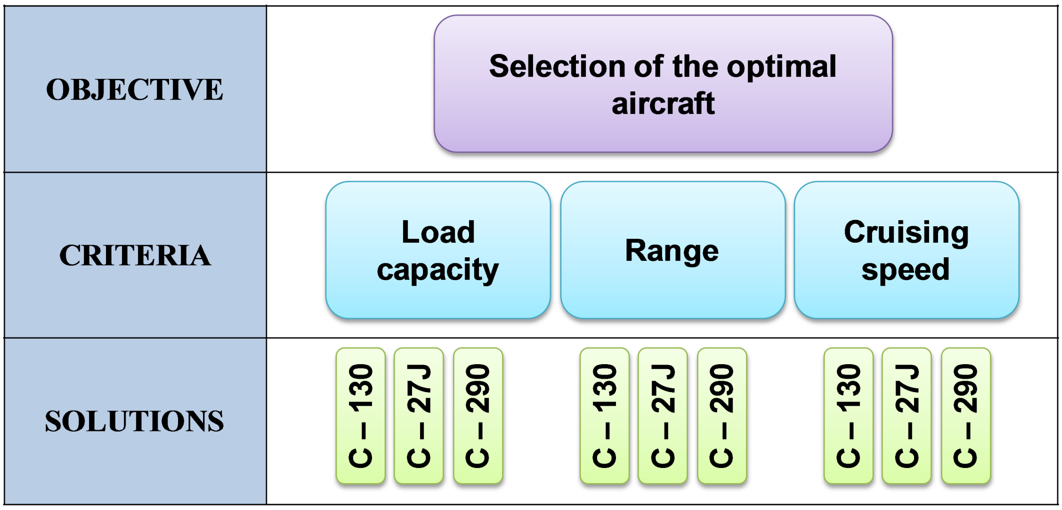


Figure 1 – Hierarchical structure selection of the optimal aircraft

According to the execution order of AHP analysis, following a hierarchy of decision–making problem, compare the pairs of criteria that will affect the choice of solution of the problem. This leads to the formation of the matrix, presented in the form of Table 2, which lets you specify which criterion is important for decision–makers due to the solution of the problem. It was assumed that the overriding criterion is the capacity of the aircraft.

Table 2 – Comparison criteria in pairs

	Load capacity	Range	Cruising speed
Load capacity	1.00	-	-
Range	**0.33**	1.00	-
Cruising speed	**0.14**	**0.25**	1.00

3.2. The results of the analysis

The Table 3 shows the results of the analysis carried out AHP. The columns are presented criteria selected to comparative analysis. In rows are given the various types of aircraft used in the analysis and so:

- O1 – C–130 HERCULES,
- O2 – C–27J SPARTAN,
- O3 – C–295 Chaff CASA.

Table 3 – The results of the calculations AHP

	Load capacity	Range	Cruising speed	AHP
O1	0,430	0,147	0.043	**0,620**
O2	0,174	0,016	0.024	0,213
O3	0.052	0.102	0.013	0.167
			∑	**1**

On the basis of this analysis and with certain criteria can be concluded that the optimum air to carry the 9000 kg of strategic goods from Wroclaw to Kabul is C–130 HERCULES.

4. SUMMARY

The presented method AHP is used in the decision–making processes already over 30 years and very well fulfils its job. The literature shows that this method is universal and can be used anywhere you need to choose. It should be noted that the results obtained through the AHP are equivocal, but in the case of the choice of an appropriate means of transport the importance may have additional factors such as the cost of delivery, time of delivery and transport of strategic goods also security. Therefore it would be necessary here the consultation with technical experts in the field. But the method AHP successfully can be used as a support in the decision–making process.

5. REFERENCES

[1] Czyżewska W.: *Podejmowanie decyzji gospodarczych przy wielorakości celów. Optymalna polityka banku centralnego.* Zakład Badań Statystyczno-Ekonomicznych Głównego Urzędu Statystycznego i Polskiej Akademii Nauk, Warszawa 2001, 37–56.

[2] Tułecki A., Król S.: *Modele decyzyjne z wykorzystaniem metody Analytic Hierarchy Process (AHP) w obszarze transportu*, Problemy Eksploatacji, 2007, t. 2, 171–179.

[3] Saaty T.L.: *Fundamentals of Decisions Making and Priority and Theory with the Analytical Hierarchy Process*. RWS Publications, Pittsburgh 1994.

[4] Saaty T.L.: *The Analytic Hierarchy Process*. RWS Publications, Pittsburgh 1998.

[5] Saaty T.L.: *Decision making for leaders; The Analytic Hierarchy Process for decisions in a complex world*. RWS Publications, Pittsburgh 2001.

[6] Downarowicz O., Krause J., Sikorski M., Stachowski W.: *Zastosowanie metody AHP do oceny i sterowania poziomem bezpieczeństwa złożonego obiektu technicznego. Wybrane metody ergonomii i nauki o eksploatacji*. Politechnik Gdańska, Gdańsk 2000, 7–42.

[7] Łękawa Z.: *Metoda AHP w ocenie zdolności kredytowej jednostki samorządu terytorialnego*, Uniwersytet Ekonomiczny, Wrocław 2011, 28–76.

CREATING CUSTOMER VALUE THROUGH THE USE OF DATA

Anna RYMASZEWSKA[1], Petri HELO[1]

[1]University of Vaasa, Department of Production
Wolffintie 34, 65200 Vaasa,
Finland

Abstract:

This paper is aimed at exploring the potential for determining the true nature of customer value, as well as ensuring that this value is provided to the customer. The main focus is on manufacturing companies that decided on a shift towards offering product-service systems, which is supported by the utilization of the latest technological developments, namely the Internet of Things (IoT). The paper proposes a revised approach to the process of data gathering, as well as utilization thereof.

Keywords:

customer value, Internet of Things, lean

1. INTRODUCTION

In the context of global turbulent economy of today, where competition is no longer limited by location, organizations are gradually becoming aware of the necessity to not only establish, but also regularly revise and rethink their competitive advantage. This is particularly valid nowadays, when the “rules of the game” are easily disrupted by the advancements in technology.

In general terms, the notion of competitive advantage comprises of all these attributes that determine organization’s ability to perform significantly better than its competitors. Literature quotes several sources of competitive advantage however, the focus of this paper is on customer value specifically.

Competitive advantage is often associated with creating a successful value proposition, which has long been considered both a theoretical and practical challenge, starting with determining what value is, continuing with ensuring that the value is delivered to customer while simultaneously generating profit for the organization.

Lean as a manufacturing and management philosophy has earned its position of a prominent research topic by offering organizations possibilities for achieving greater efficiency and productivity of operations without the necessity to engage more resources. The aspect of value creation is one of the principles upon which the concept of lean is based [1]. Lean as a management concept has been evolving towards exploring better ways of determining, extracting, and ultimately, offering value to customer. [2] claim that the next frontier in the development of lean is its role in the process of customer value creation, since the potential of lean is still far away of being fully explored. Furthermore, in order to reflect the conditions of the modern economy, the value creation process is perceived from the perspective of the Internet of Things (IoT) powered servitization, which aims at creating customer value through the use of data.

Based on findings by [3] who explores the role of information in building competitive advantage, and [4] who proposes customer value as a source of competitive advantage, this paper aims at exploring the potential for combining the advancements in lean thinking, and the dynamically developing concept of the Internet of Things (IoT), towards the improved process of creating and appropriating customer value. The research presented in this paper focuses on large organizations transitioning from pure manufacturing operations towards offering complete product-service systems (PSS). In other words, the organizations are undergoing the servitization process. The transition is enabled by IoT powered processes of real-time data collection and analysis. This paper proposes a revised approach to creating and appropriating customer value by combining the principles of lean thinking (value creation in particular) with the latest technological advancements, namely the Internet of Things (IoT). The novelty of the research and the uniqueness of its contribution are realized by combining the fields of research that have been sparsely researched in such configuration.

The paper is structured as follows. Focused literature review chapter is followed by the description of the research design and methodology. Next, the empirical part of the study, based on three case companies, is presented, and followed by the analysis of findings. Based on the empirical evidence and literature review, a conceptual framework is proposed. The paper closes with conclusions and suggestions for further research.

2. THEORETICAL BACKGROUND

2.1. On value

Defining vale has been challenging and scholars have adopted various perspectives which result in different definitions. Since this paper focuses on superior customer value creation and delivery thereof, the closer overview over definitions of customer value is provided. [4] defines customer value in terms of its orientation on organization's customers. The focus is in particular on what customers want and what they believe they are getting from buying and using the product.

One of the classic definitions of customer value is provided by [5] who claims that "value is the consumer's overall assessment of the utility of the product based on perceptions of what is received and what is given" (p. 14). [6] define customer value through the lens of the emotional bond that is created at the moment of purchasing a product or service. The emotional bond relates to customers and providers and only occurs after a product or service has been used and customer has concluded that a given product or service provides an added value.

[7] distinguishes between use value and exchange value. Use value is customer's subjective valuation of consumption, while exchange value is defined in terms of the amount that a customer actually pays.

Customer orientation as a potential new source of competitive advantage is in itself not a novel approach. [4] claims that after the rather inward looking possibilities for building a sustained competitive advantage, companies should adopt a more outward looking approach that assumes customer orientation that aims at "superior customer value delivery". This claim supports the general shift of sources of value which are now seen as being knowledge and information rather than financial capital [8,3]. According to [9] creation of superior customer value can be achieved when customer's perceived benefits are increased and/or perceived customer sacrifice is reduced as compared to competitors.

The aforementioned definitions suggest that the customer value is a concept that is still open to subjectivity, since every customer will use their own judgment to determine what added value means. Moreover, according to [4] customers' perceptions of value might differ at the time of purchase, during and after using a product. Even though the author refers to products in particular, it might be stated that the same rule will be true in case of purchasing services or product–service systems (PSSs).

This claim is further supported by [10] who outlines three main phases that provide a complete overview of customer experience cycle which comprises of pre-purchase (perceptions about value might be shaped by earlier experiences, word of mouth, brand image and reputation), exchange (what customer experiences during transaction, shaped by the characteristics of the transaction environment, sales personnel, and delivery performance), use (customer experience during use, maintenance, and disposal).

[4] also suggests a strong relationship between the concepts of customer value and customer satisfaction which stems from the shared reliance upon the evaluative judgements. Customer satisfaction has been a subject of scientific research as well as one of the most frequently measured performance indicators. However, customer satisfaction should in fact be just a foundation for further efforts that are aimed at achieving the customer delight since [11] quote that companies are frequently unable to retain customers even if they are claim to be satisfied. Moreover, the authors claim that delighted customers are much more likely to repeat their purchases and therefore, might turn into loyal customers, as well as recommend a company's products or services to other people.

When discussing value, it is important to distinguish between value creation and appropriation since those two elements need to be fulfilled if an organization wishes to build a sustained competitive advantage.[12] states that value is captured when an organization receives customer payment, despite competitors' attempts to appropriate these payments, while simultaneously being able to retain these payments. According to [12] value creation occurs when a customer is either willing to pay for a novel benefit or be willing to pay more for a product or a service that she or he perceives to be better. Alternatively, customer might choose to receive a previously available benefit at a lower cost, which will then result in greater volumes being purchased.

2.2. Mechanisms for value creation, co-creation, and appropriation

[7] define value creation in terms of combining the acquired use values of resources and, through the actions of organization's members, transforming them into a greater level of perceived value for customers. [9] state that creation of superior customer value is realized when an organization increases the perceived benefits while simultaneously reducing customers' perceived sacrifice and, most importantly, excelling the competitors.

Since profit generation will only occur if customers are willing to purchase a product or service, the process of value creation also needs to engage customers and therefore, a term of value co-creation is introduced. [13] defines value co-creation in terms of a collaborative model of marketing and innovation where a customer or consumer is essential and integral resource in the process of value creation. [14] define value co-creation in terms of company and customer creating value jointly, rather than company trying to please customer. Furthermore, while co-creating value, problems are defined solved jointly in an environment of a constructive dialogue.

Even though value creation is inarguably a critical aspect of company's operations, it itself it is not enough to achieve financial success [15]. The authors define value appropriation in terms of extracting profits in the marketplace and highlight that both are necessary for achieving competitive advantage, while organizations having a considerable degree of freedom in deciding on which one to prioritize.

2.3. IoT and value

[16] define the Internet of Things as " interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications" (p. 1647).

[17] highlight the important breakthrough elements of IoT such as the ability to enhance the competitiveness of various vertical markets, as well as broadening the scope of business opportunities available. The latter can be achieved by bridging vertical markets through applications that use a common ICT platform, enabling growth of new markets and applications, as well as optimizing business processes by utilizing advanced data analytics techniques.

As the potential of customer value creation is continuously unfolding, it is challenging to exactly determine the terms in which the customer value creation can be expressed. [18] claim that value created by the utilization of IoT can be expressed in terms of identification of visibility, tracking location, collection and provision of the right information in the right time, improved operations and flow, reduced waste in manufacturing processes, as well as the new approaches to maintenance and product life-cycle.

Furthermore, [19] emphasize that in the case of IoT, its value is not in the things but rather in the data gathered and possibility to analyze them in order to generate powerful insights which can be translated knowledge, both practical and theoretical. [19] state that the data driven insights can be utilized directly in process improvement. Process transformation and improvement will, in turn, create unique opportunities for value creation. [19] claim that when processes optimized with the help of IoT, they can yield a variety of desired results such as enhanced quality of products and services, reduced costs, improved decision making, and faster innovation.

2.4. Lean and value

Lean philosophy has originally developed as an approach to achieving greater efficiency and productivity without resorting to increased use of resources [1]. With the development of the concept and the widespread of Toyota's success story (Toyota Production System – TPS), lean has become a complete approach to management gradually adopted and adjusted by companies towards their own version of lean enterprise, which [20] labells as XPS.

However, according to [21] and [9] the implementation of lean production in itself is not enough for creating a competitive advantage based on value, unless a company is capable of appropriating the value that it created. Value appropriation, in simple terms, implies being capable of extracting profits from the value created [15].

Based on the focused literature review it can be concluded that the topic of value creation and appropriation still requires additional research especially in the context of the challenges of modern economy and technological development which enables brand new possibilities of value creation and appropriation. Nowadays organizations are even more able to reconnect with their customers regardless of their position in the value chain. The research presented in this paper offers an innovative approach to the subject of customer value creation which now can be attained much easier with the IoT. Simultaneously, this goal is connected to the development of the next frontier of lean, which is described in terms of creating customer value [2]. In the context of the research presented in this paper, customer value creation and co-creation has been identified as a challenge due to a characteristic that all studied companies share namely long life-cycles of the products they offer as well as the distance to customer located on the far end of value chain. Based on those identified challenges, this paper is an attempt to explore the opportunities for both creating and co-creating value with the help of IoT powered servitization. Moreover, the opportunities for pushing forward the frontiers of lean, described in terms of increased possibilities of customer value creation, are also examined and expressed in a form of a conceptual framework.

3. RESEARCH DESIGN AND METHODOLOGY

The research presented in this paper employs the case study method with the focus on the analysis of qualitative data. According to [22] case study research "enables researcher to answer "how" and "why" questions, while taking into consideration how a phenomenon is influenced by the context within which it is situated" (p. 556). Furthermore, [22] highlight the important benefit of the case study method which is enabling researcher to "gather data from a variety of sources and converge the data to illuminate the case" (p. 556).

The choice of methodology was determined by the nature of the research which is also supported by [23] guidance on when to use case study. The author claims that the case study research is particularly beneficial in answering the "how" and "why" questions, where behavior cannot be manipulated during the study, contextual conditions are important for the study and they need to be acknowledged. Moreover, the boundaries between the studied phenomenon and context are often difficult to be separated from each other.

This paper utilizes a combination of exploratory and descriptive case study research. The main focus is on qualitative data gathered in large manufacturing companies transitioning from offering only products towards offering product-service systems (PSS). Furthermore, the studied companies have decided to facilitate their servitization processes by utilizing the latest technological developments in the field of the Internet of Things. In practice, the advancements of IoT are used for remote maintenance in particular.

Multiple cases study approach is utilized which also implies multiple data sources [23]. Documentation and interviews with managers responsible conducting the shift towards servitization were the main sources of data, with each data source contributing to building the understanding of the studied phenomenon [22]. The focus of data collection and analysis is on qualitative input as such data was deemed the most appropriate from the perspective of addressing the research objectives stated in this paper.

3.1. Case companies

Three case companies were chosen for the study. All of them are large manufacturing organizations that are undergoing a process of transitioning from offering products to offering product-service systems. The companies are all operating in B2B environment and therefore, the possibilities for determining the customer value is particularly difficult since from the perspective of positioning in the value chain, end customer is far away. Therefore, all the studied companies are facing the same challenge of reconnecting with the customer.

4. DATA ANALYSIS AND RESULTS

Table 1 provides a concise summary of the different paths to servitization chosen by the case companies.

Table 1 – Overview of the case companies

Company	Brief description	Servitization profile	The role of IoT
A	Provider of machinery for sheet metal processing, focus on complete production lines.	PSS is constructed around the internet connection of the machines. The initial system configuration may change due to changes in customer portfolio, and e.g. what has been optimized in the commissioning phase may not be optimal any more.	Real-time information regarding production and essential KPIs. Information is stored in a centralized cloud system
B	Provider of power generators. Depending on a project, scope of supply.	Redeveloped maintenance system which replaces scheduled maintenance activities with maintenance that is based on the actual performance of a product rather than predictions (condition based maintenance-CBM).	CBM data is collected from the machinery and, with the help of sensors, is compared to upper and lower control limits. Daily data values are transmitted to central CBM team for analysis and periodical reports delivered to clients.
C	Technology provider to power generation and distribution. Offering large power transformers used in electricity distribution networks	Increasing the traditionally low automation level in transformers. Condition thereof is tracked and monitored by sensors. Data related to currents, voltages, frequencies, temperatures and oil quality are tracked and monitored.	Automated logging device with Internet connection. Transformer is connected to utility local intranet and providing the real-time view on each power transformer operation for the end-user.

Table 2 – Identified challenges and value popositions based on IoT powered servitization

Company	Challenges (customer pains)	Solution and Value proposition
A	Life-cycles of the products offered are long and there is not much customer contact after commissioning. The initial system configuration	*Fleet management system*- providing an opportunity to see actual production and daily KPIs. The focus is on hierarchy of machines at different locations. Increased performance of the equipment combined with optimized maintenance ensures lower OPEX.
B	Inefficient maintenance system that generates costs and does not provide customer with enough reliability. Scheduled maintenance does not moderate sufficiently moderate the risk of unexpected breakdowns.	Remote view on assets for the purpose of effective condition based maintenance (CBM). CBM reduces risk of expensive, non-planned interruptions, ensures improved asset utilization for customer. Customer value is provided by improving reliability of the machinery, as well as decreasing the total cost of ownership.
C	Low level of automation. In is difficult to access or gather real-time and actual operational data, and it might require manual operations.	Automated logging device with Internet connection which provides real-time view on power transformer operations for end users. Having access to this kind of data supports the proper utilization and therefore, extended life-cycle of the product.

Case companies have designed their IoT powered servitization processes with a purpose of creating and appropriating customer value. With the help of IoT companies were able to shorten the distance to customer as well as gather and analyze the real-time data regarding the actual use of their product which, in turn, could be used in order to fine-tune companies' PSS as well as the value proposition itself.

[24] state that designing a successful customer value proposition is based simply on the ability to precisely identify those aspects that are causing customers most inconvenience ("customer pains"), while simultaneously being able to relieve these pains better than competitors would do. We use the findings by [24] to capture the customer value in the three studied companies. Table 2 presents an overview of the identified areas of concern and how the studied organizations decided to relieve them with the help IoT powered servitization.

5. THE CONCEPTUAL FRAMEWORK

The three studied companies have crafted their customer value proposition based on the identified difficulties experienced by the end customers during the course of using the end products. The servitization process was developed as an extension of the competences that the case companies already have based on the years of experiences as manufacturers. The shift towards being providers of "complete solutions" was primarily driven by the possibility to expand the scope of profit generation. Since the products offered by the case companies are complex and so is the utilization thereof, the companies centered the offered PSSs around the common goal of enabling more effective utilization, elimination of breakdowns, better maintenance, based on what exactly is happening, rather than what the companies think that might be going on.

Due to the characteristics of the offered products as well as the specifics of operations, crafting a successful value proposition was challenging to achieve. From the value chain perspective, the studied companies are rather far away from the final customers. Without knowing exactly what customers perceive as value or how the products are being used, the case companies were rather limited in their options for designing successful value propositions. Nevertheless, the companies were able to benefit from the opportunities that the IoT brings by shortening the distance to their customer and gathering valuable, real-time data at a relatively low cost.

Based on the empirical evidence of the IoT powered servitization and the latest developments in the literature, a conceptual framework for creating customer value through the use of data is proposed. The proposed framework is based on two elements combined- value creation and appropriation. Value creation is based mainly upon the IoT element which enables data collection and analysis. As it was stated before, data itself is not valuable until is transformed into valuable information and to knowledge. Value appropriation is facilitated through the lean component.

The proposed framework also employs lean thinking in order to enable value appropriation, which combined with value creation provides a sufficient basis for creating competitive advantage that can be sustained. In the context of rapid changes in economy, which translates into easily disrupted business processes, the notion of competitive advantage might no longer be valid in its traditional form, which is doing something significantly better than competitors while safeguarding the advantage by building as many entry barriers as possible [25]. According to [25] in highly uncertain, complex, and fast-moving environments, the aforementioned definition of competitive advantage might not be valid any more.

According to [26] the main challenge with leanness and customer value is that even though it is one of the guiding principles of lean however, there is rather a sparse evidence of how can customer value can be realized in practice. Furthermore, the authors highlight that it is difficult to label an activity as waste without knowing exactly what customer considers as wasteful and what not. Therefore, the understanding of customer processes is of essential importance here.

Therefore, the framework in this paper proposes a revised approach to looking at the aspect of competitive advantage that assumes an innovative approach to creating and appropriating customer value towards satisfied customers, greater customer retention, and increased profitability. Such an approach supports the claim by McGrath [24] who state that nowadays competitive advantage should also be a subject to iterations and changes rather than an assumption that once acquired, will last.

In the proposed framework value creation if facilitated by making the correct use of data gathered with the help of IoT, while value appropriation is supported by lean techniques.

Figure 1 presents the conceptual framework for value creation and appropriation. IoT component enables real-time data gathering and analysis which foundational for defining how products perform and how customers use them on a daily basis. This is an important input from the perspective of building a deeper understanding of customer needs and expectations towards the product. Moreover, the data on product performance enables the fine-tuning and improving the offered PSSs. The proposed lean component is based upon the principle of eliminating waste. Since defining of value-added activities is ultimately customer's role, the notion of waste and elimination thereof can be revised towards delivering value faster and more effectively. This, in turn, might lead to the increased customer satisfaction which leads to repeated purchase. In case of the studied companies, offering products characterized by long life-cycles, it is more justified to describe the proposed framework in terms of building long-term relationships sustained by the superior value offering, realized by the service proposition. Therefore, the framework proposes the value creation is realized through the IoT component, and value appropriation-through the lean component.

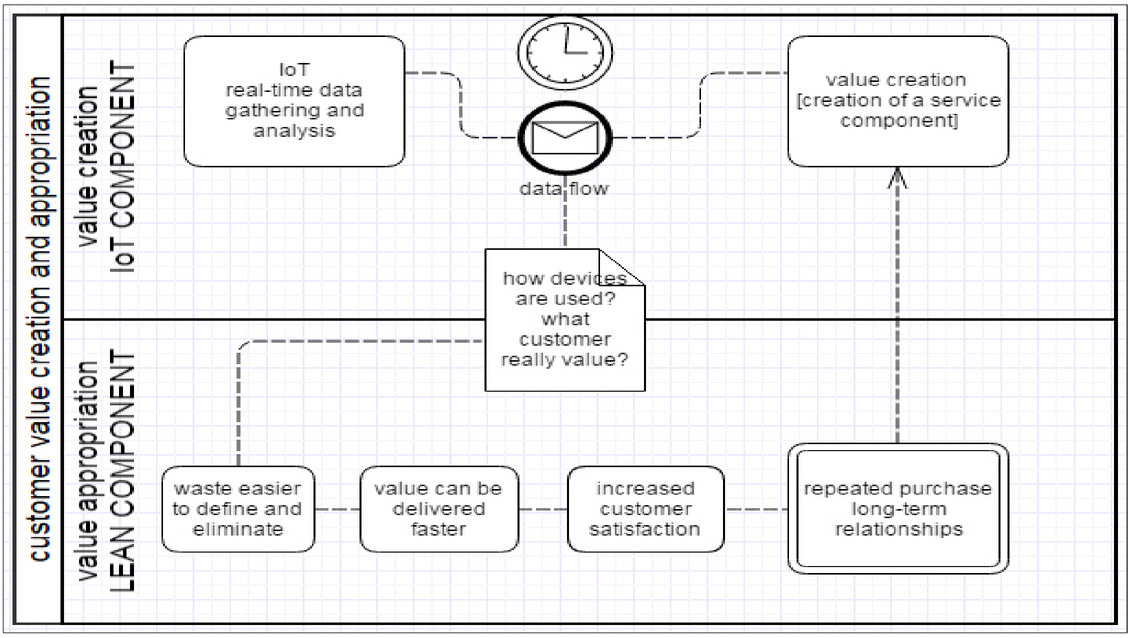


Figure 1 – The proposed conceptual framework

6. CONCLUSIONS AND FURTHER RESEARCH

The research presented in this paper is an attempt to connect value creation and appropriation with the well-established concept of lean as well as the relatively new concept of the Internet of Things (IoT). Evidence found in literature confirms that the concepts of customer value creation and appropriation are the important area of research, with many aspects still remaining to be explored. Therefore, this study explores the new opportunities for value creation that are enabled by the advent of IoT which is a breakthrough in terms of being able to gather the real-time data on how devices are being used by customers.

This paper emphasizes that IoT driven value creation is in fact strongly connected with lean principles. Lean, at its core, is aimed at removing waste or, in other words, non-value adding activities. However, what remains unclear is how organizations determine what customers really see as a value. Literature quotes numerous methods for measuring customer satisfaction in different moments varying from purchase, utilization, after-sales service. Nevertheless, the methods are limited to exploring only a snapshot of reality and might require a considerable effort from the customer as well (in terms of for example filling in surveys repeatedly). With the rapid technological development and the introduction of IoT, also the concept of listening to the voice of customer (VOC) can be pushed to the next frontier. Before the IoT became popular, the Internet allowed for unlimited connection between people. This broadened the possibilities for customer interaction yet, certain aspects of customer experience might still be difficult to capture based on the opinions expressed. Therefore, the new possibilities of tracking customer experience that the connected devices offer provide new insight into customer value creation and appropriation that is explored in this study. Furthermore, the proposed framework for value creation and appropriation can be discussed from the perspective of possible consequences for logistics as for instance, additional benefit of CBM can be expressed as an opportunity to decrease logistics costs since scheduled maintenance can be replaced by intervening when needed.

The approach presented in this article explores how the IoT can be used to provide improved customer value. Moreover, customer value is approached from the perspective of lean and improvement of processes which is realized through the elimination of waste. Notion of waste is redefined towards being drawn directly from what customers perceive as unnecessary and possible to eliminate.

We propose the further development of the work presented in this paper that could be realized by refining and testing empirically in companies transitioning from pure manufacturing to offering product service systems.

7. REFERENCES

[1] Womack, J.P., Jones D.T., Roos D.: *Machine that changed the world*. Simon and Schuster, New York 1990.

[2] Duncan, E. Ritter R.: *Next frontiers for lean*. McKinsey Quarterly, 2(2014), 82–89.

[3] Porter, M.E., Millar V.E.: *How information gives you competitive advantage*, Harvard Business Reviev, July–August(1985), 149–152.

[4] Woodruff, R.B.: *Customer value: the next source for competitive advantage*. Journal of the academy of marketing science, 25(2)(1997), 139–153.

[5] Zeithaml, V.A.: *Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence*, The Journal of marketing, (1988), 2–22.

[6] Butz, H.E., Goodstein, L.D.:*Measuring customer value: gaining the strategic advantage.* Organizational dynamics, 24(3)(1997), 63–77.

[7] Bowman, C., Ambrosini V.:*Value creation versus value capture: towards a coherent definition of value in strategy*, British Journal of Management, 11(1)(2000), 1–15.

[8] Allee, V., Taug J.: *Collaboration, innovation, and value creation in a global telecom*. The Learning Organization, 13(6)(2006), 569–578.

[9] Gulyaz, E., van der Veen J.A., Venugopal V., Solaimani, S.: *Improving SME Competitiveness Through Lean: Value Creation and Appropriation Perspective*, Proceedings of the 26th Annual POMS conference, Washington DC, 8–11 May 2015.

[10] Woodall, T.: Conceptualising'value for the customer': an attributional, structural and dispositional analysis, Academy of Marketing Science Review, (1)2003.

[11] Thomassen J.P., de Haan E.: *How to create a service excellence organization*, http://www.customerdelight.nu/content/05-nieuws/01-nieuwsitem-a/whitepaper_service-excellence.pdf., 15-05-2015.

[12] Priem, R.L.: *A consumer perspective on value creation*. Academy of Management Review, 32(1)(2007), 219–235.

[13] Bhalla, G.: *Value Co-Creation*. In: *Wiley International Encyclopedia of Marketing*, N.K. Malhotra (Ed.), Wiley-Blackwell, 2009.

[14] Prahalad, C.K., Ramaswamy V.:*Co-creation experiences: The next practice in value creation*, Journal of interactive marketing, 18(3)(2004), 5–14.

[15] Mizik, N., Jacobson, R.: *Trading off between value creation and value appropriation: The financial implications of shifts in strategic emphasis*, Journal of marketing, 67(1)(2003), 63–76.

[16] Gubbi, J., Buyya R., Marusic S., Palaniswami, M.: *Internet of Things (IoT): A vision, architectural elements, and future directions*. Future Generation Computer Systems, 29(7)(2013), 1645–1660.

[17] Miorandi, D., Sicari S., De Pellegrini F., Chlamtac I.: *Internet of things: Vision, applications and research challenges*, Ad Hoc Networks, 10(7)(2012), 1497–1516.

[18] Fantana, N.K., Riedel T., Schlick J., Ferber S., Hupp J., Miles S., Michahelles F., Svensson S.: *IoT applications–value creation for industry*. In: *Internet of Things: Coverging Technologies for Smart Environments and Integrated Ecosystems*, O.Vermesan, P. Friess (Eds.), River Publishers, Aalborg, 2013, 153–206.

[19] Noronha, A., Moriarty R., O'Connell K. Villa N.: *Attaining IoT Value: How To Move from Connecting Things to Capturing Insights*, (2014), http://www.cisco.com/c/dam/en_us/solutions/trends/iot/docs/iot-data-analytics-white-paper.pdf., 15-05-2016.

[20] Netland, T.: *Exploring the phenomenon of company-specific production systems: one-best-way or own-best-way?*, International Journal of Production Research, 51(4)(2013), 1084–1097.

[21] Lewis, M.A.*: Lean production and sustainable competitive advantage*, International Journal of Operations & Production Management, 20(8)(2000), 959–978.

[22] Baxter, P., Jack, S.: *Qualitative case study methodology: Study design and implementation for novice researchers*, The Qualitative Report, 13(4)(2008), 544–559.

[23] Yin, R.K.: *Case study research: Design and methods*, 3rd edn. Applied Social Research Methods Series, vol. 5, Sage Publications, Thousand Oaks, 2003.

[24] Osterwalder, A., Pigneur, Y., Bernarda, G. and Smith, A.: *Value Proposition Design: How to Create Products and Services Customers Want*. John Wiley & Sons, New Jersey, 2014.

[25] McGrath, R.G.: *Business models: a discovery driven approach*, Long Range Planning, 43(2)(2010), 247–261.

[26] Found, P. Harrison R.: *Understanding the lean voice of the customer*, International Journal of Lean Six Sigma, 3(3)(2012), 251–267.

BUSINESS INTELLIGENCE IN MANAGING OF TECHNICAL-INFORMATION SYSTEM

Goran SAVIĆ[1], Ljerka LUIĆ[2]

[1]Karlovac University of Applied Science
Ivana Meštrovića 10, Karlovac,
Croatia
[2]Karlovac University of Applied Science
Ivana Meštrovića 10, Karlovac,
Croatia

Abstract:

The reason for conducting research on information systems (IS) of maintenance, monitoring and diagnostics was to detect the role and importance of Business Intelligence (BI) and Logistic Information System (LIS) in managing the technical system of transformers. The research included hardware and software basis of information systems. By a comparative analysis of the IS functionality and relevant bibliographic sources, as well as synthesis of the data collected, the following descriptive metrics were determined: the advantages and disadvantages of the application of BI. Using methods of induction, analogy and generalization, final considerations were summarized and a main conclusion was identified: Business Intelligence (BI) affects the efficiency of managing technical-information system (TIS) of transformers.

Keywords:

business intelligence, logistic information system, technical-information system, managing

1. INTRODUCTION

Business Intelligence (BI) is a very large set of applications and technologies used for collecting, storing, analyzing and allowing appropriate access to data to help users make better and quicker business decisions. What is very important to achieve using Business Intelligence is for the final display of data not to be designed only for IT professionals, but also for business users who will undertake the necessary activities based on the results of the Business Intelligence system.

If Business Intelligence is viewed from the perspective of an information system (IS), it allows users to analytically process data, monitor and predict trends, and give answers to business questions. The purpose of Business Intelligence is to transform large amounts of data into information [1].

Information technology (IT) provides new technical and business possibilities which substantially alter the structure of traditional technical and business systems. They change the existing industrial structure and create an atmosphere where successful competition relies on the ability to improve existing services by using modern information technology [2].

2. TECHNICAL SYSTEM BUSINESS INTELLIGENCE

The development of controlling, measuring and computing technologies has allowed for the implementation of a single technical system for operational business management of electric distribution facilities, which ultimately results in a concept of integral maintenance, monitoring and diagnostics of all its elements, as described below on the example of transformers [3].

2.1. Information System Hardware

The transformer monitoring information system hardware consists of a subsystem installed in the transformer (information system cabinet and sensors installed in the appropriate places in the transformer, Figures 1 and 2) and a computer (server) located in the control office. The transformer subsystem consists of a monitoring system cabinet and sensors.

Inside the cabinet are the controller (an industrial network device with its own processor and memory) and other system devices:
- circuit breakers,
- an uninterruptible power supply device,
- cabinet micro-climate controllers,
- signal overvoltage and overcurrent protection devices.

Figure 1 – Oil level sensor on the transformer conservator [4]

The information system server and cabinet are connected by optical cable. They communicate using a TCP/IP (Transmission Control Protocol/Internet Protocol) set of protocols. The information system server is an industrial computer with hard disks operating in a RAID (Redundant Array of Independent Disks) mode. When the system operates for an extended period of time, the data collected in the database becomes an important part of the entire system and, as long as system components and programs may be replaced, only the data in the database is irrecoverable. The use of two disks to hold the database prevents data loss in case one of the disks fails.

Figure 2 – Information system cabinet [5]

2.2. Information System Software

The information system software presented in Figure 3 comprises:

- e–Trafo Origin is a controller application that collects and processes signals from the sensors and sends them to the server,
- e–Trafo Spot is an application that receives monitoring results, additionally processes them and forwards them to be stored in the database,
- e–Trafo Anywhere is a client application presenting monitoring results to the user on a server or a remote computer,
- Tag Engine is a program that transmits data from the controller to the server and records it in the database,
- the database is used to store collected and processed data in the information system server,
- the signal overvoltage and overcurrent protection device protects all controller input modules against overvoltage and power surges from the sensors and feeder cables,
- the transducer is equipped with an AD converter that digitalizes the signal and a DA converter that converts such digitalized signal into standard signal. [5]

Data is presented (in tabular or diagram format) locally (on the system server) or remotely (on a remote computer). In case the system is accessed remotely, data is transferred from the server to the remote computer by using a secure fast protocol and is presented through e–Trafo Anywhere in the same way as it is on the information system server.

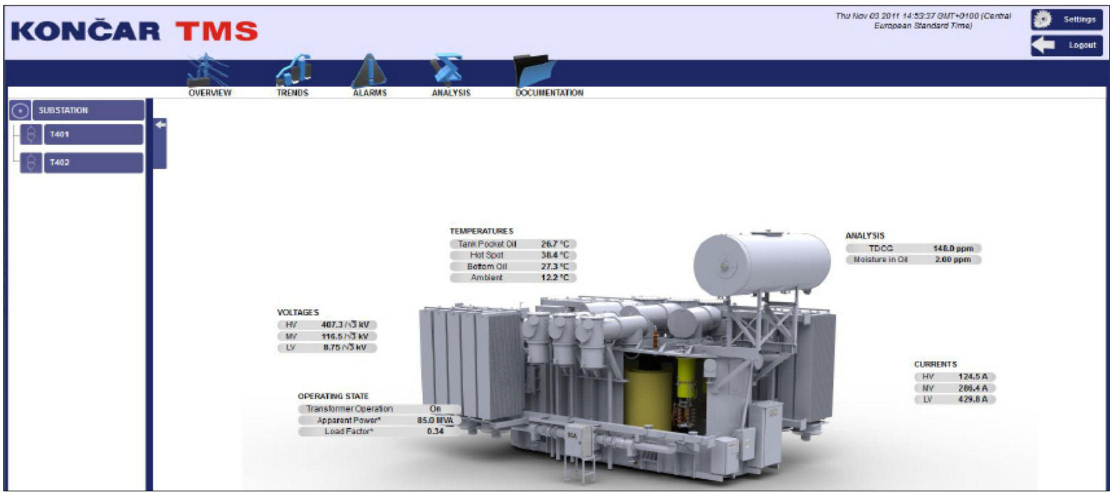


Figure 3 – Information system user interface [5]

2.3. Information System

An information system is a set of interconnected parts (hardware, software, people, procedures, information and communication networks) aiming to obtain and transfer data and information required for the functioning and management of technical and business systems. A computer-based information system comprises people (trained to use a computer) and hardware and software made, designed and operationalized to be used to collect, record, process, store, find and display information in an appropriate format [6].

Electricity market participants need to set their business objectives, where only the result is relevant. The reliability of facilities, plants and devices in an electric distribution system should be constantly maintained on a high level. Reliable operation of transformers in distribution networks thus gains importance. A transformer maintenance, monitoring and diagnostics information system is a modern product using numerous modules and measurement, protection, analysis, evaluation, forecasting, communication, archiving, reporting and network operation tools that operate synchronously and perform maintenance, monitoring and diagnostics functions for the purpose of providing users with timely information about the condition of transformers and preventing failures (minimizing their consequences). Analyzing data contained in the information system is the quickest way to establish feedback, enhance the effect of using the transformer maintenance, monitoring and diagnostics strategy, and obtain information necessary to make any adjustments on the transformer [7].

2.4. Logistic Information System

Information Systems (IS) play a major role in developing and sustaining competitive advantage in the global marketplace. The Logistics Information System (LIS) is part of the information system of the organization that is integrated in the Business Intelligence (BI) and is correlated with the Technical-Information System (TIS). Contemporary information communication technologies and logistic information systems based thereon become strategically significant in domain of Technical-Information System (TIS) application. Information technology obviously significantly changes competitive prospects of all activities, products and services and affects all activities we are engaged in, what we do and not only how we do it [8]. Contents of this paper shows the significance of application of IT technologies and BI in domain of managing of TIS, shown through advantages and disadvantages on the transformer maintenance, monitoring and diagnostics.

2.5. Maintenance Information System

Maintenance is a set of activities performed for the purpose of maintaining machines and devices in such a condition to allow them to effectively perform their intended functions. The purpose of maintenance is to repair any failures while minimizing the costs of labor and material and to minimize machine interruptions for eliminating failures and making the necessary repairs. Maintenance has developed parallel with the development of industrial production. Technical equipment is becoming increasingly complex, with measuring and controlling technology elements being used, new materials and design solutions appearing and maintenance technologies being developed, including instruments for determining and measuring parameters relevant to evaluating the condition of tested technical equipment and forecasting future behavior of technical equipment.

A maintenance information system is organized collection of information and production and launching of information carriers to ensure that information is transferred to the place where it will be used, stored and processed. After receiving feedback, information is selected, grouped and processed to ensure that maintenance decisions (maintenance work and spare parts planning) are made as easily as possible. The core of an information system is a single maintenance object database. Maintenance objects include equipment, devices or components, buildings and all electric distribution technical systems being maintained. Creating a maintenance object database is one of the most significant and comprehensive activities in a maintenance information system implementation project. Such maintenance object database should be meaningfully defined and hierarchically structured [it must allow for unambiguous definition of the technical system→subsystem→component (element, device) connections]. It is necessary to define the structure and method of naming maintenance objects (to facilitate database searching). Each maintenance object in the information system is assigned attributes that define its location, the person responsible (maintenance engineer) and the cost center responsible for the maintenance costs. In addition to basic particulars, a certain number of technical particulars may be stored in the maintenance object database for each element (e.g. type, serial number, manufacturer, purchase date and exploitation start date) [7,9].

2.6. Transformer Monitoring Information System

A transformer monitoring information system presents the condition of the transformer and the conditions in which the transformer operates in real time. Transformer monitoring is continuous oversight of transformer condition, which includes:

- measuring certain physical values of the transformer,
- monitoring of transformer equipment condition,
- evaluating certain parameters based on measurements and mathematical models,
- archiving measured and evaluated parameters,
- an expert diagnostic system for each part of the transformer, and
- a user interface allowing access to monitoring results.

The following objectives are achieved by installing a monitoring information system in the transformer:

- detection of errors as they arise or minimizing the consequences of failures,
- constant presentation of operating conditions and transformer condition,

- condition-based maintenance,
- more reliable operation,
- transformer management optimization (estimation/extension of useful life),
- more detailed analysis of failure causes, and improved human safety and environmental protection.

Parameter monitoring implies collecting parameter values (through measuring or evaluation), storing them in the database and presenting the relevant information to the user. Measurements are performed by using sensors installed in the transformer, while parameter evaluation is performed in the software tools installed in the monitoring information system based on the values of the measured parameters and transformer data. In addition to parameter monitoring, other tools are installed in the system (alarms and trends) that are used to collect real-time information relevant to transformer's operation. The purpose of a monitoring information system is to collect, process, present, exchange and archive technical information about the transformer to prevent any failures or minimize their consequences by duly informing users about the condition of the transformer [10].

2.7. Transformer Technical Diagnostics Information System

Technical diagnostics includes procedures to define defects in machines, plants, equipment and devices based on tests, measurements and inspections [11]. Operational readiness, reliability and availability of a transformer as an electromagnetic device are highly important for the delivery of generated electricity into the transmission network. Assessment of transformer's condition and its operational readiness, exploitation risk analysis and determining the necessary interventions to be undertaken are only possible by using a large number of various measuring and testing methods and analyzing the trends of changes in particular values, and by monitoring the condition over an extended period of time. In addition to damage to equipment, losses resulting from failures also include losses due to interruption of operation and delivery of electricity. The answers to complex questions concerning transformer exploitation may only be obtained based on accurate and reliable measuring and testing methods, regular diagnostic monitoring, a complex and integral approach to transformers as complex systems, and using databases and specific expert knowledge. Such approach to transformer condition diagnostics is used to detect on time and at the earliest stage any disruptions that may result in failures, unplanned interruptions or disasters, and to monitor trends and estimate the remaining useful life of a transformer. The use of information technologies (databases) may significantly improve the existing technical diagnostics and quality of operation. Using a database containing data necessary for technical diagnostics is an advantage. It is much more efficient to hold all data in an integral unit. Connecting the relevant applications with the database allows for efficient searching of different data, obtaining data in the appropriate form, and comparing different statistical processes and analyses [12].

3. RESULTS

Transformer maintenance, monitoring and diagnostics is a highly complex, responsible and expensive process that requires trained professionals in various areas, as well as expensive and modern equipment and devices. The selection and implementation of an information system is a comprehensive task that requires establishing an appropriate expert team. [13].

The advantages of using Business Intelligence in the management of a technical information system based on transformer maintenance, monitoring and diagnostics information system analysis are:

- availability of information and data about transformer operation from any place and at any time,
- all information and data about the transformer are contained in a single integrated unit,
- ongoing comparison of measured and required (set) values,
- allows transformer remote control,
- improves the planning of all maintenance activities,
- increased operational reliability of the plant,
- favorable environmental effects,
- enhanced workplace safety,
- detection of errors at the earliest stage and prevention or minimization of consequences of failures, and
- transformer management optimization (estimation/extension of useful life).

The disadvantages of using Business Intelligence (BI) in the management of a technical information system based on transformer maintenance, monitoring and diagnostics information system analysis are:

- high initial investment in modern mobile information & communication technologies, and
- operational staff's lack of training for and interest in using Business Intelligence and
- full implementation of a technical information system [14].

4. CONCLUSION

Equipping a transformer with a maintenance, monitoring and diagnostics technical information system is important for collecting information necessary to assess the condition and improve the management of a transformer. Such transformer maintenance, monitoring and diagnostics information system is an important component of electric distribution plants, especially with respect to the prevention of transformer failures, protection of staff and the environment, and improved transformer management. Secure access to data and information by using Business Intelligence (BI) and a maintenance, monitoring and diagnostics information system, as well as assessment of equipment condition and operating conditions, significantly increase the operational reliability of a transformer, while early warnings about potential failures and their causes significantly reduce the incidence of failures and their consequences. [15] The development of an electric distribution system requires constant reduction of operating costs and increase of transformer availability. One of the ways to achieve such goals is to use a technical information system for transformer maintenance, monitoring and diagnostics. The liberalization of the electricity market has set new, more stringent requirements for secure electricity supply, whereby the reliable operation of transformers in electric distribution networks gains importance [14,15].

5. REFERENCES

[1] Cvitaš, A.: *Extraction of information systems in business intelligence*, https://www.fer.unizg.hr/_download/repository/AnaCvitasKvalifikacijskiIspit.pdf, 2016-02-26.

[2] Luić, Lj.: *Information systems*, Karlovac University of Applied Sciences, Karlovac, 2009.

[3] Kuzle, I.: *Diagnostics in maintaining elements of the power system*, https://www.fer.unizg.hr/_download/repository/Dijagnostika_elemenata_EES-a.pdf, 2016-02-16.

[4] Keitoue, S.: Transformer Monitoring System,http://www.koncar-institut.hr/docs/koncarinstEN/documents/13/Original.pdf, 2015-10-15.

[5] Banović, M.: *Končar TMS – Transformer monitoring system*, http://bib.irb.hr/datoteka/267438.Banovic_Elektroenergetika-TMS_clanak.pdf, 2015-10-10.

[6] Pavić, M.: *Information systems*, Školska knjiga, Zagreb, 2011.

[7] Brckan, K., Karneluti J.: *Information system of maintenance of power facilities*, plant *and equipment*, HO Cired, Šibenik, 2008.

[8] Luić, Lj.: *Information Systems – Business*, *Logistics and Health Information Systems*, Karlovac University of Applied Sciencs, Karlovac, 2009.

[9] Čala, I.: *Engineering manual IP4*, *third volume – Organization of production*, Školska knjiga, Zagreb, 2002.

[10] Keitoue, S., Keller A., Murat I., Mikulecky A., Poljak M.: *Monitoring system for power transformers in distribution networks*, HO Cired, Šibenik, 2008.

[11] Novinc, Ž., Halep A.: *Technical diagnostics and monitoring in industry*, Kigen, Zagreb, 2010.

[12] Polužanski, V., Milosavljević S., Miladinović N., Delić J., Kovačević D.: *The database for the improvement of the condition diagnostics of transformers*, Infoteh, Jahorina, 2012.

[13] Srb N.: *Magnetic monitoring of electrical rotating machines*, Graphis, Zagreb, 2004.

[14] Savić G.: *Application of information system in the maintenance, monitoring and diagnostics of transformers*, Final thesis, Karlovac University of Applied Sciences, Karlovac, 2015.

[15] Skalicki B., Grilec J.: *Electrical Machines and Drives*, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, 2011.

MULTI-CRITERIA MATHEMATICAL PROGRAMMING APPROACHES FOR ASSIGNMENT OF SERVICES IN HOSPITAL

Bartosz SAWIK[1]

[1]AGH University of Science and Technology, Faculty of Management,
Department of Applied Computer Science
Al. Mickiewicza 30, PL-30-059 Kraków,
Poland

Abstract:

This work presents multi-criteria mathematical programming approaches for optimal allocation of workers among supporting services in a hospital. The services include logistics, inventory management, financial management, operations management, medical analysis, etc. The optimality criteria of the problem are minimization of operational costs of supporting services subject to some specific constraints. The constraints represent specific conditions for resource allocation in a hospital. The overall problem is formulated as a multi-criteria assignment model, where the decision variables represent the assignment of people to various jobs. Numerical examples are presented and some computational results modeled on a real data from a hospital in Lesser Poland are reported. Presented problems have been solved using AMPL programming language with CPLEX solver, with use of branch and bound method.

Keywords:

multi-criteria mathematical programming, assignment problem, services operations management, healthcare planning

1. INTRODUCTION

Hospitals typically lack effective enterprise level strategic and operational planning. Some of them do not have a good personnel organization. In most of the cases they could use some optimization models to try to improve it.

This case shows a real situation where an optimization model is applied to a real hospital in Krakow, Poland. Paper presents discussion about data collected from hospital, about models formulations used and the results obtained as well as the conclusions deducted from them.

Big institutions such as hospital not often use the kind of OR/MS methodologies used in many other service industries to help with capacity planning and management [1]. The assignment of service positions plays an important role in healthcare institutions. Poorly assigned positions in hospital departments or over-employment may result in increased expenses and/or degraded customer service. If too many workers are assigned, capital costs are likely to exceed the desirable value [2]. The supporting services have a strong impact on performance of healthcare institutions such as hospitals. In hospital departments, the supporting services include financial management, logistics, inventory management, analytic laboratories, etc. This paper presents an application of operations research model for optimal supporting service jobs allocation in a public healthcare institution.

The optimality criterion of the problem is to minimize operations costs of a supporting service subject to some specific constraints. The constraints representing specific conditions for resource allocation in a hospital were modified, compared to previous publications [3–16] according to different optimization models formulation. The overall problem is formulated as a mixed integer program in the literature known as the assignment problem [16,17,18,19,20,21]. The binary decision variables represent the assignment of people to various services.

This paper shows practical usefulness of mathematical programming approaches to optimization of supporting services in healthcare institutions. The results of some computational experiments modeled after a real data from a selected Polish hospital are reported.

2. INPUT DATA FOR COMPUTATIONS

The data for computations have been gathered from the hospital in Krakow, Poland. This hospital is a modern unit that offers medical care to a huge population. The 97.02% of all the admissions of the Hospital are patients from the Lesser Poland Region and in the last few years the admissions have reach the number of 28000-30000 patients per year. It offers services in clinics and several surgical processes, which are carried out by high-qualified personnel.

Some of the clinics that this hospital has are Neurological Clinic, Multiple Sclerosis Clinic, Dermatological Clinic, Clinic of Plastic Surgery, Otolaryngology Clinic, Radiotherapy Clinic, Urological Clinic, Clinic of Neonatology, etc.

The real data from a selected Polish public healthcare institution from one month period were used for computations. The data include 20 supporting services hospital departments in which there are 88 supporting jobs. Permanent employment is defined as a percent of permanent post between 25% (0.25) to 100% (1.00) according to the size of a job position (part-time or full time) for a selected job in a selected department. Supporting service departments in the hospital consist in total of 214 permanent employments with 221 workers employed before the optimization. Moreover, the maximal amount of money paid monthly for services in each department was used. Specific data consists of the average salaries for selected jobs in the departments defined as costs of assignment of workers to jobs. In addition, the minimum number of permanent employments for each job in each department was given, and the maximal number of positions which can be assigned to a single worker.

Table 1 shows the number of types of supporting services position in departments, the number of permanent employments in departments, the number of employees in each department before optimization and the maximal amount of money monthly paid for services in each department.

Figure 1 – Ludwik Rydygier Hospital in Krakow [23]

Table 1 – Input data used in the model

	Number of types of supporting services position in department	Number of permanent jobs in department	Number of employees in department – before optimization	Maximal amount of money monthly paid for services in department
1.Central Heating Department	5	15.5	16	29250
2.Power Department	3	15	15	31050
3.Medical Bottled Gases Department	2	6	6	11400
4.Ventilation & Air-condition Department	4	8	8	16650
5.Heating & Hydraulic Department	4	11	11	21200
6.Distribution Department	3	6	6	13600
7.Medical Equipment Department	4	6.75	8	17500
8.Technical Department	5	11	11	20950
9.Economy Department	5	21	21	31360
10.Hospital Pharmacy	11	19.5	20	43400
11.Sterilization Department	5	27	27	41500
12.Stuff Monitoring Department	5	13	13	27150
13.Information Department	4	6.5	7	16100
14.Business Executive Department	5	8	8	15450
15.Technical Executive Department	4	3.5	4	7150
16.Law Regulation Department	3	7	7	16100
17.Attorneys-at-law Department	2	2.5	4	7950
18.Hospital Management Cost Section	5	9	9	15550
19.Salary Section	5	6.75	9	15800
20.Accounting Section	4	11	11	26950
TOTAL	**88**	**214**	**221**	**426060**

The hospital provides a lot of services. First of all, it has a lot of different departments, such as department of anesthesiology and intensive care, oncology, obstetrics or radiotherapy, among others. Then, for having a diagnostic they have a laboratory, with a pathology sub-department. They offer several fields of investigation: General analysis, Clinical chemistry, Hematology and coagulation, Immunochemistry, Microbiology, Toxicology, Gynecological cytology, Blood group serology. They also have some imaging machines, which are basically radiology, mammography, ultrasound and computer tomography machines.

3. PROBLEM FORMULATION

Mathematical programming approach deals with optimization problems of maximizing or minimizing a function of many variables subject to inequality and equality constraints and integrality restrictions on some or all of the variables. In particular, 0-1 variables represent binary choice. Therefore, the model presented in this paper is defined as a mixed integer programming problem.

Suppose there are m people and p jobs, where $m \neq p$. Each job must be done by at least one person; also, each person can do at least, one job. The problem objective is to assign the people to the jobs so as to minimize the total cost of completing all of the jobs.

The optimality criterion of the defined problem is to minimize operations costs of a supporting service subject to some specific constraints. The constraints represent specific conditions for resource allocation in a hospital. The overall problem is formulated as a modified assignment problem. The decision variables represent the assignment of people among various services. Compared to previously published papers [3–16] decision variables and constraints were modified according to different optimization models formulation.

4. OPTIMIZATION MODELS

The problem of optimal assignment is formulated as a triple objective integer program, which allows commercially available software (e.g. AMPL/CPLEX [22]) to be applied for solving practical instances.

The problems of assignment are handled in two different ways and three different approaches. Firstly, each problem is solved as a bi-objective mixed integer program with use of weighted-sum approach, lexicographic approach and reference point approach. Secondly, problems are formulated as a triple-objective with the same approaches. For solving all models CPLEX solver is used.

The bi-objective models are used for optimization of allocation of personnel of a hospital. The objective is to minimize operational costs of supporting services and maximizing (or minimizing) the total number of employees. Maximization or minimization of the total number of employees depends on decision maker preferences, like service level, and cost.

The triple objective models by mixed integer programming consist of criteria as follows: operational costs of supporting services, total number of employees, total number of permanent employments. Constraints are defined to secure that the total cost of assignment of all the employees of a selected department must be less than or equal the maximal monthly budget for salaries in that department. Constraints also ensures that the total number of permanent employments in selected department must be less than or equal the maximum number of permanent employments in that department. Constraints guarantees that the minimal number of permanent employments is less than or equal the given maximum number of permanent employments. Constraints assume that the assignment of workers to selected permanent jobs type is not more than maximal requirements. Constraints also show the relation of variables, which assures that at least one staff member must be working in one job of one department of the hospital. Constraints also assures that the number of permanent employment of a selected job is less than or equal to the maximal number of permanent employments of that job of selected department.

5. COMPUTATIONAL RESULTS

In this section numerical examples and some computational results are presented to illustrate possible applications of the proposed formulations of integer programming of optimal assignment of service positions. Selected problem instances with the examples are modeled on a real data from a Polish hospital.

In the computational experiments the historical data is considered. Computational time takes only a fraction of a second to find optimal solution if any exists. The computational experiments have been performed using AMPL programming language [22] and the CPLEX v.11 solver on a laptop with Intel® Core 2 Duo T9300 processor running at 2.5GHz and with 4GB RAM.

Analysis of computational results shows the total budget, the number of employees and the number of permanent employments for each case. Values of β_1, β_2, β_3 are responsible for setting priority of each objective. For instance β_1 is connected with the total budget objective, β_2 with the number of employees and β_3 with the number of permanent employments.

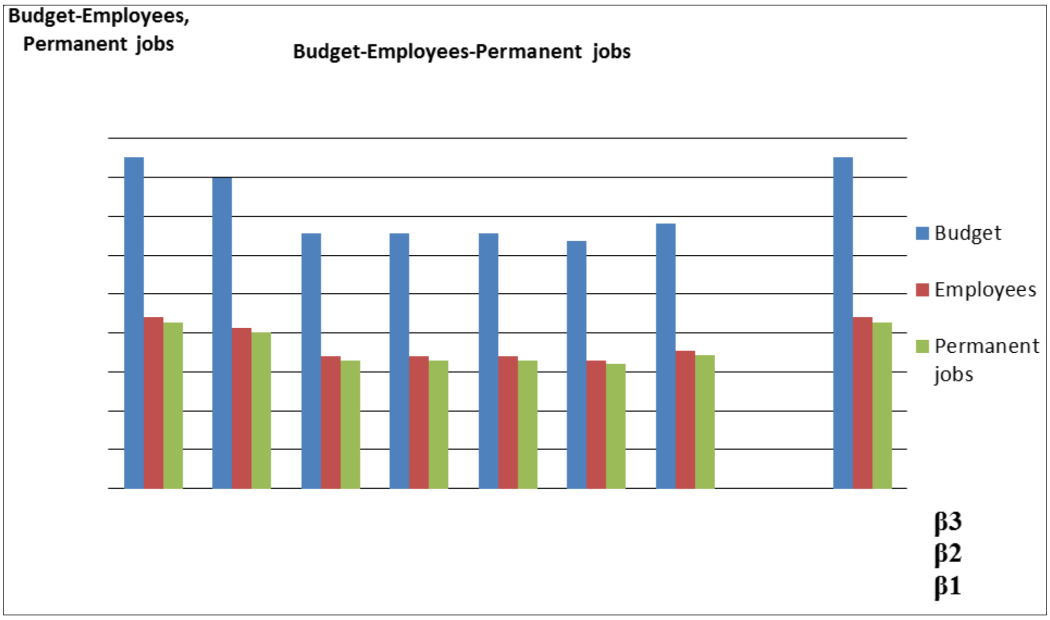


Figure 2 – Total budgets, number of employees and number of permanent jobs

In the Figure 2. it is shown that are computed values of budget, number of employees and permanent jobs. In addittion, when the value of β_2 is 0.7 we have the lowest values for budget, number of employees and permanent jobs. We can also see, that when β_2 is 1 all the values are 0 due to the fact that we do not have any constraint for the number of employees or the number of permanent employments. Moreover, when β_1 = 1000 or β_3 = 1000 the results are more or less the same with the maximum number of employees and permanent jobs and the maximal total budget too.

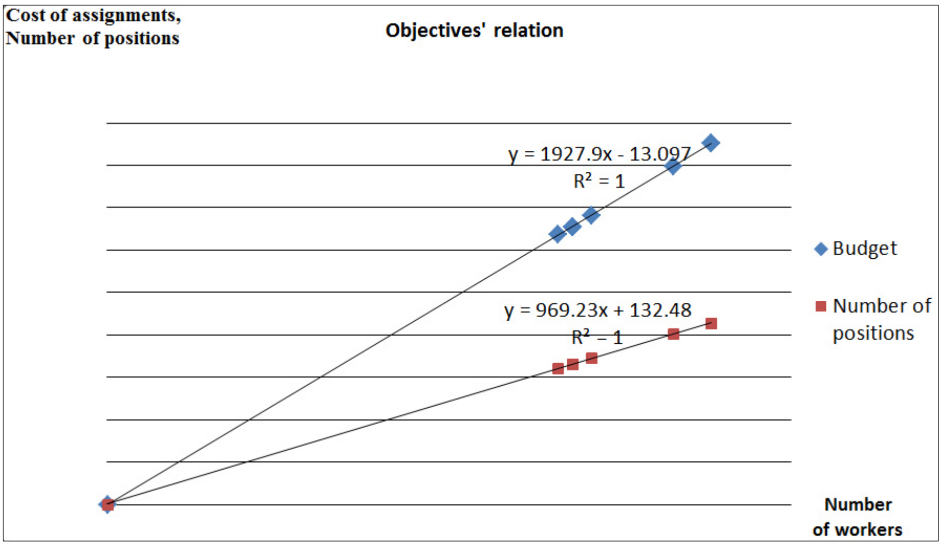


Figure 3 – Objectives' relation in the triple objective model

By looking at this graph (Figure 3) we are able to see that the relation between the number of positions and total budget with the number of employees is a linear relation. Logically if we increase the number of workers, the number of permanent positions and the total budget increase as well.

6. CONCLUSIONS

Operations research techniques, tools and theories have long been applied to a wide range of issues and problems in healthcare.

The allocation of personnel in a hospital is an important factor. It is possible to use an optimization models to find optimal solutions for these types of problems. One possible method is the branch and bound method with the weighted-sum, lexicographic or reference point approach. It is possible to solve the problem with different objective functions and the results must be studied and analyzed deeply.

This paper proves the practical usefulness of mathematical programming approach to optimization of supporting service in a hospital. The results of computational experiments modeled after a real data from a hospital in Lesser Poland indicate that the number of hired workers can be reduced in almost all departments of the hospital.

The proposed modified multi-objective assignment problem and weighted-sum, lexicographic or reference point approach can be easily implemented for management of supporting services in another institution, not only healthcare. Obtained results consist of the monthly expenses for salaries, the number of workers and the amount of permanent employments needed for jobs in all considered supporting service departments.

Computational time takes only a fraction of a second to find the optimal solution because of a relatively small size of the input data. Presented optimization model is NP-hard, but computable. Implementation of reference point method ensures to obtain results with non-dominated set of solutions. The global optimums for considered three objective functions are presented.

Considered approaches used models with the weighted-sum functions. Computational results shown how varying the values of the weights of the objective function can make a lot of changes in the results obtained. In the bi-objective model it is more easily to see the variations of values due to the changes of weights but in the triple-objective is not so easy to conclude some solutions.

Health care is a really important issue in the society, what is why it is too important to have health care institutions well developed and organized. There are a lot of problems in hospitals such as delays in the Emergency Rooms, low bed occupancy levels, wrong allocation of treatments or disagreement of the personnel with the schedule, as well as nurse rostering problems.

All over the years these problems have been treated with solutions carried out by manually processes. Nowadays, to make this easier we can take advantage of computational methods and approaches, which use optimization models to improve health care institutions' work.

Therefore, to realize the allocation of personnel in a hospital it is a good idea to use an optimization model. Applied method in this research was the branch and bound algorithm with the weighted sum approach which helps to fix the assignment of services in one Polish hospital. It is possible to solve the problem with different objective functions and the results must be studied and analyzed deeply.

7. ACKNOWLEDGEMENT

The author is grateful to the anonymous reviewers for their comments. This work has been partially supported by NCN grant # DEC-2013/11/B/ST8/04458 and by AGH University of Science and Technology.

8. REFERENCES

[1] Green, L.V.: *Capacity planning and management in hospitals* in *Operations Research and Health Care,* (Eds.: Brandeau, M. L. and Sainfort, F, Pierskalla W. P.), Kluwer Academic Publishers, Boston, USA, 2004.

[2] Brandeau, M.L., Sainfort, F, Pierskalla, W.P.: *Operations Research and Health Care,* Kluwer Academic Publishers, Boston, USA, 2004.

[3] Sawik, B.: *Weighted-sum approach to health care optimization*, Applications of Management Science, 17(2015), 163–180, Emerald Group Publishing Limited, ISSN: 0276-8976/doi:10.1108/S0276-897620140000017012

[4] Sawik, B.: *Lexicographic approach to health care optimization*, Applications of Management Science, 17(2015), 181–201, Emerald Group Publishing Limited, ISSN: 0276-8976/doi:10.1108/S0276-897620140000017013

[5] Sawik, B.: *Health care optimization problem formulations with weighted-sum, lexicographic and reference point approaches*, MOTSP 2015, Brela, Makarska, Croatia 2015.

[6] Sawik, B.: *Application of multi-criteria mathematical programming models for assignment of services in a hospital*, Applications of Management Science, 16(2013), 39–53, Emerald Group Publishing Limited, ISSN: 0276-8976/doi:10.1108/S0276-897620130000016006.

[7] Sawik, B.: *A multi-objective mathematical programming model with conditional value-at-risk for assignment of services in a health care institution*, Management of Technology Step to Sustainable Production (MOTSP) 2013, May 29–13, 2013, Novi Vinodolski, Croatia.

[8] Sawik, B.: *A single and triple-objective mathematical programming models for assignment of services in a health care institution*, Int. J. Logistics Systems and Management, 15(2–3)(2013), 249–259.

[9] Sawik, B.: *Multi-Criteria Mathematical Programming for Assignment of Services in a Healthcare Institution*, Conference Proceedings – The International Conference on Industrial Logistics (ICIL) 2012, June 14-16, 2012, University of Zagreb, Zadar, Croatia, 161–167.

[10] Sawik, B.: *Assignment of Supporting Services in a Healthcare Institution using Multi-Criteria Mathematical Programming*, The International Conference on Industrial Logistics (ICIL) 2012, June 14–16, 2012, Zadar, Croatia.

[11] Sawik, B.*: A bi-objective portfolio model for supporting services in a hospital*, INFORMS 2012 Annual Conference – Informatics rising, October 14–17, 2012, Institute for Operations Research and the Management Science, Phoenix, USA, 2012.

[12] Sawik B.: *A Reference Point Method to Triple-Objective Assignment of Supporting Services in a Healthcare Institution*, Decision Making in Manufacturing and Services, 4(1–2)(2010), 37–46.

[13] Sawik B.: *Reference Point Approach to Assignment of Supporting Services in a Healthcare Institution*, chapter in: Świerniak A., Krystek J. (Eds.) *Automatics of Discrete Processes, Theory and Applications*, Vol. 2, Monographic of the Silesian University of Technology, PKJS, Gliwice, Poland 2010, 187–196.

[14] Sawik B., Mikulik J.: *An Optimal Assignment of Workers to Supporting Services in a Hospital*, Polish Journal of Medical Physics and Engineering, 14(4)(2008), 197–206.

[15] Sawik B., Mikulik J.: *Model for Supporting Service Optimization in a Public Health Care Institution*, EFOMP council and officer's meeting, 14th general assembly of the Polish Society of Medical Physics, European Conference Medical Physics and Engineering 110 years after the discovery of Polonium and Radium, 17–21 September 2008, Kraków, AGH, Polish Academy of Science, Poland.

[16] Sawik B.: *Bi-Objective Integer Programming Approach to Optimal Assignment of Supporting Services in a Health-Care Institution*, The 21st Conference of the European Chapter on Combinatorial Optimization (ECCO XXI) May 29–31, 2008, Dubrovnik, Croatia.

[17] Bowman Jr, V.J.: *On the relationship of the Tchebycheff norm and the efficient frontier of multi-criteria objectives*, In: Thiriez H., Zionts S. (Eds.) *Multiple Criteria Decision Making*, Lecture Notes in Economics and Mathematical Systems, Vol. 130. Springer-Verlag, Berlin, Germany 1976, 76–86.

[18] Burrkard R, Dell'Amico M, Martello S.: *Assignment Problems,* SIAM, Philadelphia, USA, 2008.

[19] Ehrgott M.: *Multicriteria Optimization,* Second edition, Springer, Berlin, Germany, 2000.

[20] Nemhauser G.L., Wolsey L.A.: *Integer and Combinatorial Optimization*, John Wiley & Sons, Toronto, Canada, 1999.

[21] Steuer R.E.: *Multiple Criteria Optimization: Theory, Computation and Application*, John Wiley & Sons, New York, USA, 1986.

[22] Fourer R., Gay D.M., Kernighan B.W.: *A Modeling Language for Mathematical Programming*, Management Science, 36(1990), 519–554.

[23] www.szpitalrydygier.pl Last access Jun 2016

BI-OBJECTIVE OPTIMIZATION MODELS FOR GREEN VRP APPROACHES

Bartosz SAWIK[1], Javier FAULIN[2], Elena PÉREZ-BERNABEU[3], Adrian SERRANO-HERNANDEZ[2]

[1]AGH University of Science and Technology, Faculty of Management, Kraków, Poland
[2]Public University of Navarre, Pamplona, Spain
[3]Universitat Politècnica de València, Alcoi, Spain

Abstract:

This research presents a mathematical programming formulation of green vehicle routing bi-criteria problems. The problems deal with G-VRP for routes crossing Navarre, Basque Country and La Rioja, Spain. The most significant bi-objectives for finding optimal routes are the minimization of the travelled total distance by the running vehicles versus the minimization of altitude differences within the route; the minimization of total distance versus the minimization of the carbon emission. Bi-Objective optimization models used mathematical programming formulations of multi traveling salesman problems. Constraints ensure that all vehicles begin and end their routes at the depot. The subtours solutions are going to be avoided. Weighted-Sum approach is implemented to solve multi-objective green vehicle routing optimization problems. The results of some computational experiments modeled after a real data from the Spanish food distribution company are reported.

Keywords:

Bi-Objective Decision Making, Green Logistics, Green Vehicle Routing, Mathematical Programming.

1. INTRODUCTION

This paper shows practical usefulness of bi-criteria mathematical programming for Green Vehicle Routing (G-VRP) for optimization of logistic services in the Spanish food distribution company. The results of some computational experiments modeled after a real data are reported.

Freight transportation planning includes many aspects, particularly when viewed from the multiple level of decision maker. The most famous problem at this level is Vehicle Routing Problem (VRP). VRP has been studied since 1959 with the objective to minimize the total distance traveled by all vehicles.

This paper shows practical usefulness of mathematical programming approaches to bi-objective optimization of green traveling salesman (TSP), transportation and vehicle routing problems (G-VRP) in the Spanish food distribution company. The results of some computational experiments modeled after a real data from a selected Spanish company are reported [1,2].

Traveling salesman problems (TSP) can be divided into two types: symmetric and asymmetric. Symmetric Traveling salesman problems (STSP) require less computation processor units (CPU), in general. The asymmetric traveling salesman problems (ATSP) are more demanding from computational point of view. Most common generalization of TSP is multiple traveling salesman problems (mTSP), where more than one salesman allowed to be used in the solution [1,2].

In order to reduce the environmental impact from transportations, it is necessary to know the level of CO_2 emissions. The easier way to find this value is to firstly know the fuel consumption. Methodology for solving this problem and to determine the level of the fuel consumption can be found in many papers [2–7].

Altitude difference – the road gradient is important due to the fact, that the wheel horsepower demand increases on a slope and this will significantly affect fuel consumption. The size of the vehicle is also very important because the difference of fuel consumption from a small vehicle and a big one is remarkable.

Also the use of green freight corridors enables reductions in CO_2 emissions and in fuel consumption, and in the future should improve the environmental performance of road freight transport. For many years, the most important requirement has been to minimize the total distance travelled by vehicles or total time taken into the delivery.

It is only in the latest years when fuel consumption and CO_2 emissions have been taken into account as important issues. So after, they started to study a similar problem called Green VRP.

2. EROSKI GROUP

The largest part of Spain's powerful cooperative group Mondragon Corporación Cooperativa is the distribution arm, called Eroski Group [8]. The Eroski group is one of the leading chains of the Spanish retailing market. Currently Eroski is Spain's fourth largest supermarket chain [9]. It operates more than 800 supermarkets throughout Spain. Under the name Eroski, besides supermarkets, there can also be find petrol stations and travel agencies. The company was founded in 1969 in the regions of Biscay and Basque Country in Spain as a co-operative between ten smaller consumer cooperatives in the region. Its headquarters located in Elorrio, Biscay. The name given, Eroski, is a combination of the Basque words "erosi" (to buy) and "toki" (place), which can be translated as "buying place" [8].

3. INPUT DATA FOR COMPUTATIONS

The real input data for computational experiments have been provided by the Spanish supermarket chain Eroski. The problem proposed is focused in the region of Navarra, Basque Country and La Rioja where the company has its sailing points and warehouses. The depot is Elorrio, located in Basque Country, is the first node of the transportation, from where all trucks are shipped to the other destinations, 27 of them will be studied here, most of them located in Navarra. One of the restrictions to take into account is that all locations can only be visited once, except the depot, as it is showed in models presented in this paper. It is important to know the difference of altitude in between two nodes of the route; this will give information of how is the road, if the gradient of the road is positive or negative. In case that it has negative values; the fuel consumption will be higher, and the CO_2 emissions, too. In this research the carbon dioxide emissions will be taken into account, because this will affect on the environmental costs of the company and surroundings.

In the following table (Table 1.), the names of all nodes where the transportation route has to go through are written in alphabetical order.

Table 1 – Input data used in the model

Alegria-Dulantzi	Burlada	Logroño	Santa Cruz de Campezo
Alsasua	Calahorra	Orkoien	Tafalla
Araia	Carcastillo	Pamplona	Tudela
Artajona	Cizur	Rada	Villaba
Autol	Estella	Salvatierra	Vitoria
Beriain	Irurtzun	San Adrian	
Berriorzar	Lodosa	Sangüesa	Elorrio

The data provided by Spanish food distribution company shows the information of all orders and deliveries done in two months. The data includes the date of the orders and deliveries along with the amount of trucks used to carry out their orders. The capacity of the trucks it is showed in pallets and rolls, from here on it will be all the time measured in pallets.

In order to know the demand for each point, it is important to know the amount of supermarkets located in each location, because depending on it, one point will have more demand than others. In the data provided, this information can be obtained. It is showed the amount of pallets delivered to each point to each supermarket along with the date of order and delivery.

This data is determinant to make a decision on which truck to send, it will depend of how many pallets are needed.

4. PROBLEM FORMULATIONS, ALGORITHMS AND APPROACHES

Mathematical programming approaches deal with optimization problems of maximizing or minimizing a function of many variables subject to inequality and equality constraints and integrality restrictions on some or all of the variables.

Bi-objective models for transportation can be divided into three groups: transportation, traveling salesman and vehicle routing problems [2,6]. There are several ways to solve bi-objective transportation problems with environmental aspects [1,2,5,6,10,11,12,13].

Different algorithms have been considered to solve these types of aforementioned optimization problems [3,14]. Christofides [4] formulated optimization problem for transportation, which is referred to as the vehicle routing problem and is a generalization of the multiple travelling salesman problem.

5. OPTIMIZATION MODELS

Optimization problems are formulated as a bi-objective mixed integer program, which allows commercially available software (e.g. AMPL/CPLEX [15]) to be applied for solving practical instances.

Modifications of optimization models published by [7,16] for G-VRP are presented below. New models include not only reformulation of most constraints, but also bi-objective formulations and additional objectives, like altitude difference.

For optimization/minimization of CPU times, all computations have been done several times with use of different versions of subtours elimination constraints. Presented below constraint (10) is just one example of used subtours elimination.

Examples of Green Vehicle Routing (G-VRP) bi-objective model are formulated in subsections 5.1 and 5.2.

Notations for both models are presented in Table 2.

Table 2 – Table of notations

Indices

m – vehicles

n – nodes (depot and customers)

Input parameters

λ – weights for objectives - for altitude difference objective and for CO2 emission objective

a_{ij} – altitude difference between customer (node) i and customer (node) j [m]

d_{ij} – distance between customer (node) i and customer (node) j [km]

e_{ij} – (full load) – emission ration – preferably highest emission per km with full truck's load [kg CO2/km]

q_j – load demanded by customer (node) j and load supplied by customer/depot (node) j [pallets]

Q_k – maximum capacity of load (cargo) in vehicle k [pallets]

t_{ij} – driving time/distance (average per km) between customer (node) i and j [km]

T_k – maximum allowable driving time/distance (based on average time per km/average speed in driving trucks)

Decision variables

$x_{ijk} \in \{0,1\}$, i=1,…,n, j=1,…,n, k=1,…,m; i<>j – if vehicle *k* visits customer (node) *j* immediately after customer (node) *i*

$y_{ik} \geq 0$, i=1,…,n, k=1,…,m – amount of goods shipped to customer (node) *i* in vehicle *k* [pallets]

5.1. Total distance vs. altitude differences

Bi-objective G-VRP model with minimization of total distance and minimization of altitude differences is formulated as follows (1):

Minimize

$$\lambda \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} d_{ij}x_{ijk} + (1-\lambda)\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} a_{ij}x_{ijk} \tag{1}$$

subject to

$$\sum_{j=1}^{n}\sum_{k=1}^{m} x_{1jk} = m \tag{2}$$

$$\sum_{i=1}^{n}\sum_{k=1}^{m} x_{i1k} = m \tag{3}$$

Constraints (2) and (3) ensure that all vehicles begin and end their routes at the depot.

$$\sum_{k=1}^{m} x_{ijk} = 1, \quad i = 2,...,n, \quad j = 2,...,n \tag{4}$$

Constraint (4) guarantees, that a single vehicle visits each node, except the depot.

$$\sum_{i=1}^{n} x_{ijk} = 1, \quad j = 2,...,n, \quad k = 1,...,m \tag{5}$$

$$\sum_{j=1}^{n} x_{ijk} = 1, \quad i = 2,...,n, \quad k = 1,...,m \tag{6}$$

Constraints (5) and (6) assure that each node, except the depot, is linked only with a pair of nodes, one preceding it and other following it.

$$\sum_{j=2}^{n} q_j x_{ijk} \le y_{ik}, \quad i = 1,...,n, \quad k = 1,...,m \tag{7}$$

Constraint (7) is responsible for relation between variable x_{ijk} and y_{ik}.

$$\sum_{j=2}^{n} q_j x_{1jk} \le Q_k, \quad k = 1...,m \tag{8}$$

Constraint (8) ensures that no vehicle can be overloaded.

$$\sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij} x_{ijk} \le T_k, \quad k = 1,...,m \tag{9}$$

Constraint (9) does not permit that any vehicle exceeds the maximum allowable driving time/distance per day T_k.

$$\sum_{i \in S}\sum_{j \notin S} x_{ijk} \ge 1, \quad S \subseteq \{1,...,n\}, \quad k = 1,...,m \tag{10}$$

One example of subtours elimination constrains (10).

$$x_{ijk} \in \{0,1\}, \quad i = 1,...,n, \quad j = 1,...,n, \quad k = 1,...,m \tag{11}$$

$$y_{ik} \ge 0, \quad i = 1,...,n, \quad k = 1,...,m \tag{12}$$

Definitions of decision variable are presented in constraints (11) and (12).

5.2. Total distance vs. CO_2 emission

Bi-objective G-VRP model with minimization of total distance and minimization of CO_2 emission is formulated as follows (13):

Minimize

$$\lambda \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} d_{ij} x_{ijk} + (1-\lambda)\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} e_{ij} x_{ijk} \tag{13}$$

Subject to (2), (3), (4), (5), (6), (7), (8), (9), (10), (11) and (12).

Both models have been solved using Exact Methods.

6. COMPUTATIONAL RESULTS

In this section numerical examples and some computational results are presented to illustrate the solutions.

In the computational experiments the historical data is considered. Computational time takes only a fraction of a second to find optimal solution if any exists. The computational experiments have been performed using AMPL programming language [15] and the CPLEX.11 solver on a laptop with Intel® Core 2 Duo T9300 processor running at 2.5GHz and with 4GB RAM.

Figure 1 – Map of the depot and delivery points

In the Figure 1 different locations and the depot are presented, with the assigned number:

- For lambda=0.1and lambda=0.25 1→6→10→8→5→2→9→7→4→3→1
- For lambda=0.5 1→7→2→9→10→8→5→6→4→3→1
- For lambda 0.75 1→10→2→9→7→8→5→6→4→3→1
- For lambda=0.9 1→10→2→9→7→4→6→5→8→3→1

In the Figure 1 it is shown where depot and delivery points are located. Below Figure 1 examples of selected obtained solutions have been presented.

Comparison of selected suboptimal route for Traveling Salesman Problem:

- Distance and Altitude: 1→3→4→7→9→2→5→8→10→6→1
- Distance and CO_2 emission: 1→6→2→8→9→5→10→4→3→7→1

7. CONCLUSIONS

Operations research techniques, tools and theories have long been applied to a wide range of issues and problems in green vehicle routing and transportation problems.

In this paper, we have discussed some green vehicle routing problems. The optimality criteria to be considered in suitable bi-criteria models were connected to environmental aspects. Thus, some mixed integer programming formulations of bi-criteria vehicle routing problems have been considered. Some mathematical models were formulated under the assumption of existence of asymmetric distance-based costs and use of homogeneous fleet. The exact solution methods were applied in order to find optimal solutions. The software used to solve these models was the CPLEX solver with AMPL programming language.

Obtained results shows, that it is possible to control and limit the carbon emissions. There is a relation between obtained distances, driving times and altitude differences within obtained solutions versus obtained values of environmental objective. This relation proves the need for consideration of green aspects of transportation together in bi-criteria models.

The researchers were able to use real data from a Spanish company of groceries called Eroski. The solved problems deal with green logistics for routes crossing the Spanish regions of Navarre, Basque Country and La Rioja. The analyses of obtained results could help logistics managers to lead the initiative in area of green logistics by saving money paid as the direct cost of fuel and minimization of pollution. Regarding future work, we are currently working in an extended version of this problem, which includes heterogeneous fleet and combination of vehicle routing and portfolio problem.

8. ACKNOWLEDGEMENT

This work has been partially supported by the National Research Center (NCN), Poland (DEC-2013/11/B/ST8/04458), by AGH, and by the Spanish Ministry of Economy and Competitiveness (TRA2013-48180-C3-P and TRA2015-71883-REDT), and the Ibero-American Program for Science and Technology for Development (CYTED2014-515RT0489). Likewise, we want to acknowledge the support received by the CAN Foundation in Navarre, Spain (Grants CAN2014-3758 and CAN2015-70473). The authors are grateful to anonymous reviewers for their comments.

9. REFERENCES

[1] Qu, Y., Bektas, T. Benell J.: *Sustainability SI: Multimode multicommodity network design model for intermodal freight transportation with transfer and emission costs*, Networks and Spatial Economics 16, 303–329.

[2] Sawik, B., Faulin J., Pérez-Bernabeu E.: *Selected Multi-Criteria Green Vehicle Routing Problems*. Chapter in: Applications of Management Science (Vol. 18) Applications of Management Science, Lawrence K.D., Kleinman G. (Eds.). Bingley, UK: Emerald Group Publishing Limited 2016, (in press).

[3] Bektas, T.: *The multiple traveling salesman problem: An overview of formulations and solution procedures*, Omega 34(2006), 209–219.

[4] Christofides, N., Mingozzi A., Toth P.: *Exact algorithms for the vehicle routing problem, based on spanning tree and shortest path relaxations*, Mathematical Programming 20(1981), 225–282.

[5] Demir, E., Bektas, T., Laporte, G., 2014a. *A review of recent research on green road freight transportation*, European Journal of Operational Research 237, 775–793.

[6] Sawik, B., Faulin J., Pérez-Bernabeu E.: *Multi-Objective Traveling Salesman and Transportation Problem with Environmental Aspects*. Chapter in: Applications of Management Science (Vol. 18) Applications of Management Science, K.D. Lawrence, G. Kleinman (Eds.), Bingley, UK: Emerald Group Publishing Limited 2016, (in press).

[7] Úbeda, S., Arcelus F.J., Faulin J.: *Green logistics at Eroski: A case study*, International Journal of Production Economics 131(2011), 44–51.

[8] Grupo Eroski, http://www.fundinguniverse.com/company-histories/grupo-eroski-history, 2016-03.

[9] Grupo Eroski, http://www.kantarworldpanel.com/es/grocery-market-share/spain/snapshot/28.02.16/, 2016-06.

[10] Jabir, E., Panicker V.V., Sridharan R.: *Multi-objective optimization model for a green vehicle routing problem*, Procedia – Social and Behavioral Sciences 189(2015), 33–39.

[11] Sawik, B., Faulin J., Pérez-Bernabeu E.: *Multi-objective transportation problem for green logistics in the Pyrenees by mixed integer programming*, MCDM 2015 – 23rd international conference on Multiple Criteria Decision Making, August 2–7, 2015, Hamburg, Germany 2015.

[12] Sawik, B., Faulin J., Pérez-Bernabeu E.: *Bi-Objective Models for Green Traveling Salesman and Transportation Problems*, The International Conference "Management of Technology – Step to Sustainable Production" (MOTSP 2016), 1–3 June, 2016, Porec, Istria, Croatia.

[13] Sawik, B., Faulin J., Pérez-Bernabeu E.: *A Multicriteria Analysis for the Green VRP: A Case Discussion for the Distribution Problem of a Spanish Retailer*, Transportation Research Procedia 2016 (in press).

[14] Faulin, J.: *Applying MIXALG procedure in a routing problem to optimize food product delivery*, Omega 31(2003), 387–395.

[15] Fourer, R., Gay D.M., Kernighan B.W.: *A Modeling Language for Mathematical Programming*, Management Science, 36(1990), 519–554.

[16] Úbeda, S., Faulin J., Serrano A., Arcelus F.J.: *Solving the green capacitated vehicle routing problem using a tabu search algorithm*, Lecture Notes in Management Science 6(2014), 141–149.

RESILIENT VS. ROBUST SUPPLY PORTFOLIO UNDER DISRUPTION RISKS

Tadeusz SAWIK[1]

[1]AGH University of Science and Technology
Department of Operations Research and Information Technology
Al. Mickiewicza 30, 30-059 Kraków,
Poland

Abstract:

Resilient and robust supply portfolios are compared in a supply chain under local and regional disruption risks. Resiliency refers to suppliers capacity to continue supplying parts in the face of random disruptions, whereas robustness aims at an equally good performance of a supply chain under varying operating conditions. A resilient supply portfolio contains suppliers protected against disruptions to optimize average or worst-case cost, while a robust portfolio equitably optimizes average and worst-case cost. The robust and resilient portfolios are obtained using stochastic mixed integer programming. The findings indicate that the more risk-averse the decision-making the closer resilient and robust portfolios.

Keywords:

Resilient supply portfolio, Disruption risks, Stochastic mixed integer programming.

1. INTRODUCTION

The low-probability and high-impact flow disruptions that occur in global supply chains may result in losses that threaten financial state of major automakers and electronics manufacturers, e.g., [1,2,3]. Recent literature on supply chain risk management focuses on the resiliency and robustness of supply chains, e.g., [4,5]. In the literature robustness is usually defined as an ability to withstand disruption with acceptable loss of performance, whereas resilience is a potential to recover quickly from disruption. Robustness aims at an equally good performance of a supply chain under varying operating conditions, whereas resiliency refers to a supply chain capacity to survive, adapt, and grow in the face of change and uncertainty. The purpose of this paper is to develop stochastic mixed integer programming formulations for selection of resilient and robust supply portfolios in a supply chain under local and regional disruption risks. A resilient supply portfolio contains suppliers protected against disruptions to optimize average or worst-case cost, while a robust portfolio equitably optimizes average and worst-case cost. The paper is organized as follows. Problem description is provided in Section 2, and stochastic mixed integer programs for selection of risk-neutral, risk-averse and robust resilient portfolios are developed in Section 3. Computational examples are presented in Section 4, and final conclusions are made in the last section.

2. PROBLEM DESCRIPTION

Consider a supply chain in which a single producer assembles various products, using a critical part type that can be manufactured and provided by multiple suppliers, $i \in I = \{1,...,\overline{I}\}$ (for notation used, see Table 1). The suppliers are located in $\overline{R}$ geographic regions and are subject to random individual local disasters as well as joint regional disasters. Let p_i be the local disruption probability of supplier *i*, i.e., the probability that parts ordered from supplier *i* are not delivered, and p^g the probability of regional disruption, simultaneously of all suppliers $i \in I^g$ in region $g \in G$. Denote by $\Omega = \{1,...,\overline{\Omega}\}$ the index set of all $\overline{\Omega} = 2^{\overline{I}}$ potential disruption scenarios, and by P_ω the probability of disruption scenario $\omega \in \Omega$ (e.g., [6]).

The producer does not need to pay for ordered and undelivered parts. However, he can be charged for the shortage of parts. Let *s* be the per unit shortage cost of parts.

The impact of disruption risks can be mitigated by additional protective investments of suppliers to maintain their normal capacity under disruption events. For example, to protect supplier against flooding, a flood wall is build. In addition, the protective investments can be combined with pre-positioning of emergency inventory of parts manufactured by the protected supplier. The inventory can be used to compensate for the loss of capacity of the other suppliers, unprotected and impacted by disruptions. The inventory quantity is linked to the protected supplier capacity and is assumed to be not greater than its normal capacity. For each supplier $i \in I$, let c_i be the normal capacity, e_i, the unit purchasing price of parts, f_i, the fortification cost and, h_i, the per unit cost of pre-positioning the emergency inventory.

Given total demand for parts, *d*, the decision maker needs to decide which supplier to select, which of the selected suppliers to protect against disruptions and how to allocate order quantity among the selected suppliers and emergency inventory among the protected suppliers to achieve a minimum total cost of suppliers protection, emergency inventory pre-positioning, and purchasing and shortage of parts.

Table 1 – Notation

		Indices
i	=	supplier, $i \in I = \{1,...,\overline{I}\}$
g	=	geographic region, $g \in G = \{1,...,\overline{G}\}$
ω	=	disruption scenario, $\omega \in \Omega = \{1,...,\overline{\Omega}\}$
		Input Parameters
c_i	=	capacity of supplier *i*
d	=	demand for parts
e_i	=	unit price of parts purchased and shipped from supplier *i*
f_i	=	fortification cost for supplier *i*
h_i	=	unit cost of pre-positioning emergency inventory of parts at supplier *i*
s	=	unit shortage cost of parts

α	=	confidence level
p_i	=	the local disruption probability for supplier *i*
p^g	=	the regional disruption probability for all suppliers in region *g*

3. 3. PROBLEM FORMULATION

In this section three stochastic mixed integer programs **R_E**, **R_CV** and **R_ECV** are developed for selection of risk-neutral, risk-averse and robust resilient supply portfolio, respectively. The resilient supply portfolio is defined ([7]) as the allocation of demand for parts among selected, unprotected and protected suppliers, $(v_1 + w_1,...,v_{\bar{I}} + w_{\bar{I}})$, (for definition of problem variables, see Table 2).

Table 2 – Problem variables

q_i	=	1, if an order for parts is placed on supplier *i*; otherwise $q_i = 0$ (supplier selection variable)
r_i	=	1, if selected supplier *i* is protected against disruptions; otherwise $r_i = 0$ (supplier protection variable)
v_i	=	the fraction of demand for parts ordered from unprotected supplier *i* (unprotected supply portfolio variable)
ω_i	=	the fraction of demand for parts ordered from protected supplier *i* (protected supply portfolio variable)
x_i	=	emergency inventory of parts pre-positioned at protected supplier *i*, in fraction of supplier's capacity c_i (inventory allocation variable)
y_i^ω	=	emergency inventory of parts pre-positioned at protected supplier *i* and used under disruption scenario *w* (inventory usage variable)
T_ω	=	the amount by which cost of portfolio in scenario *w* exceeds V aR (tail cost)
VaR	=	the targeted cost of portfolio based on the-percentile of costs, i.e., in 100% of scenarios, the outcome cannot exceed V aR (Value-at-Risk)

3.1. Risk-neutral resilient portfolio

In this subsection a mixed integer program is presented for selection of a risk-neutral resilient supply portfolio. The risk-neutral operating conditions mean that the decision maker is indifferent to portfolios that generate the same expected cost, even though the portfolios may have varying risks of worst-case cost.

In the resilient portfolio, if an unprotected supplier is subject to disruption event and fails to deliver the ordered parts, the non delivered parts can be replaced by emergency inventory pre-positioned at protected suppliers. Then, the amount $\sum_{i \notin I_\omega} dv_i$ of parts ordered from unprotected and failed suppliers $i \notin I_\omega$ can be fully or partially met with the emergency inventory $\sum_{i \in I} c_i x_i$, (I_ω is the subset of non-disrupted suppliers under scenario ω). The overall quality of the risk-neutral resilient supply portfolio can be measured by the expected cost per part, *E* (1), of suppliers protection, $\sum_{i \in I} f_i r_i / d$, the emergency inventory pre-positioning, $\sum_{i \in I} h_i c_i x_i / d$, purchasing of parts, $\sum_{i \in I} e_i (v_i + w_i)(= \sum_{i \in I} e_i (dv_i + dw_i)/d)$, of replacement parts, $\sum_{i \in I} e_i c_i y_i^\omega / d$, shortage of parts, $\sum_{\omega\in\Omega}P_\omega s(\sum_{i\notin I_\omega}dv_i-\sum_{i\in I}c_iy_i^\omega)/d$, less cost of ordered and nondelivered parts $\sum_{\omega\in\Omega}P_\omega\sum_{i\notin I_\omega}e_iv_i$.

The resilient supply portfolio aims at reducing expected losses through the optimal selection of suppliers for protection, the allocation among them the emergency inventory and the allocation of orders for parts among both the unprotected and protected suppliers. The stochastic mixed integer program **R_E** is formulated below.

Model R_E: Selection of resilient supply portfolio to minimize expected cost

Minimize Expected Cost per Part

$$E=\sum_{i\in I}(f_ir_i+h_ic_ix_i)/d+\sum_{i\in I}e_i(v_i+w_i)+\sum_{\omega\in\Omega}P_\omega(\sum_{i\notin I_\omega}(s-e_i)v_i+\sum_{i\in I}(e_i-s)c_iy_i^\omega/d) \quad (1)$$

subject to

1. Supplier selection and protection constraints:
- only selected suppliers can be protected, and emergency inventory can be pre-positioned only at protected suppliers,
- the orders for parts can be allocated among selected suppliers only,
- each selected supplier is either protected or unprotected and so are the corresponding types of orders for parts allocated among the suppliers,

$$x_i\le r_i\le q_i; i\in I \quad (2)$$

$$v_i\le q_i; i\in I \quad (3)$$

$$v_i\le 1-r_i; i\in I \quad (4)$$

$$w_i\le r_i; i\in I \quad (5)$$

2. Order quantity and emergency inventory allocation constraints:
- total demand for parts must be allocated among selected suppliers,
- for each selected supplier (unprotected and protected), the total capacity required to manufacture the ordered quantities of parts cannot exceed available capacity,
- the emergency inventory used to replace non-delivered parts cannot exceed the pre-positioned emergency inventory,
- for each disruption scenario, non delivered orders can be partially or fully replaced by using the emergency inventory,

$$\sum_{i\in I}(v_i+w_i)=1 \quad (6)$$

$$v_i\le c_i(q_i-r_i)/d; i\in I \quad (7)$$

$$w_i\le c_ir_i/d; i\in I \quad (8)$$

$$y_i^\omega\le x_i; i\in I,\omega\in\Omega \quad (9)$$

$$\sum_{i \in I} c_i y_i^{\omega} \le \sum_{i \notin I_{\omega}} dv_i ; \omega \in \Omega \tag{10}$$

3. Non-negativity and integrality conditions

$$q_i \in \{0,1\}; i \in I \tag{11}$$

$$r_i \in \{0,1\}; i \in I \tag{12}$$

$$v_i \in [0,1]; i \in I \tag{13}$$

$$w_i \in [0,1]; i \in I \tag{14}$$

$$x_i \in [0,1]; i \in I \tag{15}$$

$$y_i^{\omega} \in [0,1]; i \in I, \omega \in \Omega \tag{16}$$

3.2. Risk-averse resilient portfolio

In model **R_CV** presented in this subsection, VaR (Value-at-Risk) is the acceptable cost level above which the decision maker wants to minimize the number of outcomes and CVaR (Conditional Value-at-Risk) considers those outcomes, where costs exceed VaR. The decision maker controls the risk of high losses due to supply disruptions by choosing confidence level $\alpha \in (0, 1)$. The greater the confidence level α, the more risk aversive is the decision making. The resilient portfolios for which the total probability of scenarios with costs greater than VaR is not greater than $1 - \alpha$, are only acceptable.

Model R_CV: Selection of resilient supply portfolio to minimize expected worst-case cost

Minimize Expected Worst-Case Cost (CVaR)

$$CVaR = VaR + (1-\alpha)^{-1} \sum_{\omega \in \Omega} P_{\omega} T_{\omega} \tag{17}$$

subject to

1. Supplier selection and protection constraints: (2)–(5)

2. Order quantity and emergency inventory allocation constraints: (6)–(10)

3. Risk constraints:
- the tail cost for scenario ω is defined as the nonnegative amount by which cost per part in scenario ω exceeds VaR,

$$\begin{aligned} T_{\omega} \ge & \sum_{i \in I} (f_i r_i + h_i c_i x_i)/d + \sum_{i \in I} e_i (v_i + w_i) \\ & + \sum_{i \notin I_{\omega}} (s - e_i) v_i + \sum_{i \in I} (e_i - s) c_i y_i^{\omega} / d - VaR; \omega \in \Omega \end{aligned} \tag{18}$$

4. Non-negativity and integrality conditions: (11)–(16) and

$$T_{\omega} \ge 0; \omega \in \Omega \tag{19}$$

where T_{ω} is the tail cost for scenario ω, defined as the amount by which costs in scenario ω exceed VaR.

3.3. Robust resilient portfolio

The mixed integer program **R_ECV** for the equitably efficient optimization of expected and expected worst-case costs is formulated below. In the model **R_ECV**, F_1, (23), and F_2, (24), are normalized values of objective functions, respectively E, (1) and *CVaR*, (17), scaled into the interval [0,1]. The objective function (20) subject to constraints (21), (22) represent the so-called ordered weighted averaging aggregation of the two equally important criteria with equal weights assigned to each criterion (see, OWA aggregation, [8,9]). The nonnegative variables σ_{kl} represent, for outcome values F_k, their upside deviations from the value of λ_l, where λ_l are unrestricted variables, e.g., [5,10].

Model R ECV: Selection of robust resilient supply portfolio to equitably optimize expected and expected worst case cost

Minimize

$$\sum_{l=1}^{2} l\lambda_l + \sum_{k=1}^{2} \delta_{kl} \tag{20}$$

subject to (2)–(16), (18)–(19) and

$$\lambda_l + \delta_{kl} \ge F_k; k,l = 1,2 \tag{21}$$

$$\delta_{kl} \ge 0; k,l = 1,2 \tag{22}$$

$$\begin{aligned} F_1 = (&\sum_{i\in I}(f_i r_i + h_i c_i x_i)/d + \sum_{i\in I} e_i(v_i + w_i) \\ &+ \sum_{\omega\in\Omega} P_\omega(\sum_{i\notin I_\omega}(s-e_i)v_i + \sum_{i\in I}(e_i - s)c_i y_i^\omega / d) - \underline{E})/(\overline{E} - \underline{E}) \end{aligned} \tag{23}$$

$$F_2 = (VaR + (1-\alpha)^{-1} \sum_{\omega\in\Omega} P_\omega T_\omega - \underline{CVaR})/(\overline{CVaR} - \underline{CVaR}) \tag{24}$$

where $\underline{E}$, $\overline{E}$ and $\underline{CVaR}$, $\overline{CVaR}$ are the minimum and the maximum values of *E*, and *CVaR*, respectively

4. COMPUTATIONAL EXAMPLES

This section presents computational examples to illustrate the proposed stochastic mixed integer programming approach. The following parameters have been used for the example problems:

- $\overline{I} = 8$ suppliers, $\overline{\Omega} = 2^{\overline{I}} = 256$ disruption scenarios.
- $\overline{G} = 3$ geographic regions, $I^1 = \{1, 2, 3\}$, $I^2 = \{4, 5, 6\}$, $I^3 = \{7, 8\}$.
- Total demand for parts: $d = 100000$.
- Supplier capacity: $c = (8, 6, 9, 9, 5, 8, 8, 7) \times 10000$.
- Supplier fortification cost: $f = (50, 20, 100, 130, 45, 60, 25, 125) \times 10000$.
- Cost per part of pre-positioning emergency inventory of parts: $h_i = 2$ for all suppliers i.
- Shortage cost per part: $s = 25$.
- Regional disruption probabilities: $p^1 = 0.001$, $p^2 = 0.005$, $p^3 = 0.05$.
- The confidence level: $\alpha \in \{0.50, 0.75, 0.90, 0.95, 0.99\}$.

Supplier price per part, e_i, and disruption probability, $p^g + (1 - p^g)p_i$, $i \in I^g$, $g \in G$, are shown in Figure 1.

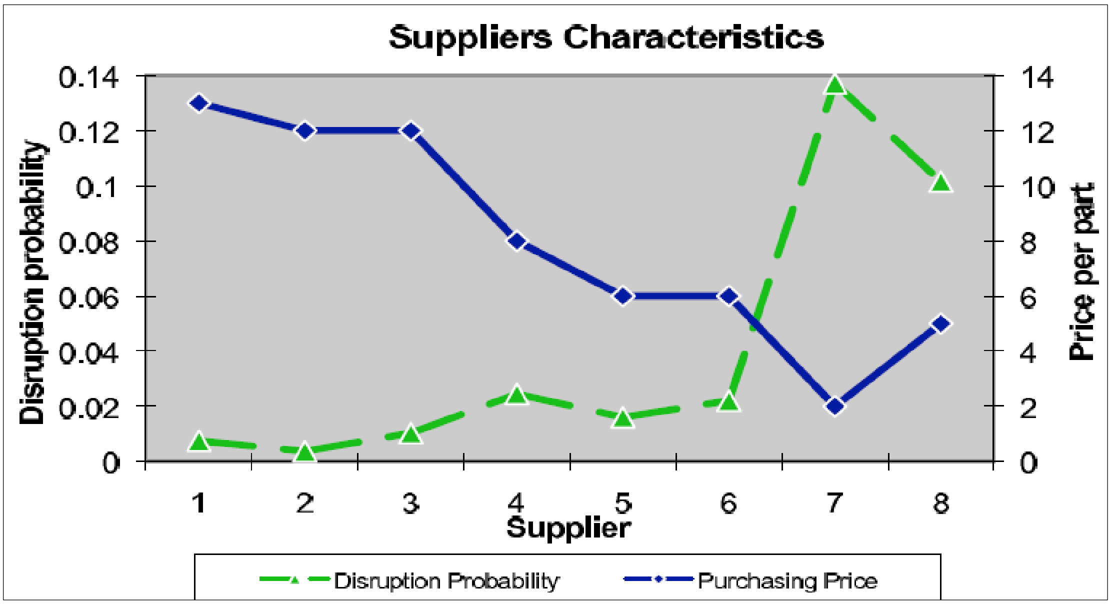


Figure 1 – Basic characteristics of suppliers

The solution results for the risk-neutral model **R_E** and the risk-averse models **R_CV** and **R_ECV** are presented in Table 3. For the resilient portfolios, suppliers 5,6,7 and 8 were only selected, of which the cheapest and the second lowest-fortification cost supplier 7 was always fortified. For the risk-averse models, the solution values of *VaR* and *CVaR* are presented along with the associated expected cost *E*. Notice for $\alpha = 0.99$, $VaR = 5.448$ is the highest cost per part that may occur and hence $CVaR = VaR = E = 5.448$. Table 3 demonstrates that the higher the confidence level, the closer the corresponding solutions to models **R_CV** and **R_ECV**.

The computational experiments were performed using the AMPL programming language and the Gurobi 6.5.1 solver (with the default settings) on a laptop MacBookPro 6.2 with Intel Core i7 processor running at 2.66GHz and with 16GB RAM. The solver was capable of finding proven optimal solutions for all examples within fraction of a second of CPU time.

Table 3 –Solutions results

Confidence level α	0.50	0.75	0.90	0.95	0.99
Model R_E: Var.=2080, Bin.=16, Cons.=2352, Nonz.=7280[a]					
E			5.349		
Suppliers Selected (% of total demand)			5(6)		
			6(7)		
			7^b(80)		
			8(7)		
Model R_CV: Var.=2337, Bin.=16, Cons.=2608, Nonz.=18024[a]					
CVaR	5.370	5.385	5.404	5.435	5.448[c]
VaR	5.348	5.372	5.372	5.372	5.448[c]
E	5.359	5.375	5.375	5.375	5.448[c]
Suppliers Selected (% of total demand)	5(7)	5(10)	5(10)	5(10)	
	6(7)				
	7^b(80)	7^b(80)	7^b(80)	7^b(80)	7^b(80)
	8(6)	8(10)	8(10)	8(10)	8(20)
Model R_ECV: Var.=2345, Bin.=16, Cons.=2614, Nonz.=20367[a]					
CVaR	5.371	5.390	5.404	5.435	5.448[c]
VaR	5.351	5.354	5.372	5.372	5.448[c]
E	5.357	5.357	5.375	5.375	5.448[c]
Suppliers Selected (% of total demand)	5(7)	5(10)	5(10)	5(10)	
	6(7)				
	7^b(80)	7^b(80)	7^b(80)	7^b(80)	7^b(80)
	8(7)	8(7)	8(10)	8(10)	8(20)

[a] Var.=number of variables, Bin.=number of binary variables, Cons.=number of constraints, Nonz.= number of nonzero coefficients.
[b] Protected supplier.
[c] E = V aR = CV aR = 5.448 is the highest cost that may occur.

5. CONCLUSION

A portfolio approach and stochastic mixed integer programming models have been proposed for supplier selection and order quantity allocation to obtain resilient or robust supply portfolios under disruptions risks. The approach proves to be computationally efficient and hence may support supply chain disruption risk management. Since the resilient portfolio aims at supplying parts in the face of random disruptions, the associated expected and expected worst-case cost are close to each other. The findings indicate that the more risk-averse the decision-making the closer resilient and robust portfolios. The future research should focus on evaluation of suppliers fortification costs versus potential losses caused by supply disruptions.

6. ACKNOWLEDGMENTS

The author is grateful to two anonymous reviewers for constructive comments. This work has been supported by NCN research grant #DEC-2013/11/B/ST8/04458, and by AGH.

7. REFERENCES

[1] Fujimoto, T., Park Y.W.: *Balancing supply chain competitiveness and robustness through virtual dual sourcing: Lessons from the Great East Japan Earthquake*, International Journal of Production Economics, 147(2013) 429–436.

[2] Park, Y., Hong P., Roh J.J.: *Supply chain lessons from the catastrophic natural disaster in Japan*, Business Horizon, 56(1)(2013), 75–85.

[3] Matsuo, H.: *Implications of the Tohoku earthquake for Toyota's coordination mechanism: Supply chain disruption of automotive semiconductors*, International Journal of Production Economics 161(2015), 217–227.

[4] Sheffi, Y., Rice J.B.: *A supply chain view of the resilient enterprise*, MIT Sloan Management Review 47(1)(2005), 41–48.

[5] Sawik, T.: *On the robust decision-making in a supply chain under disruption risk*, International Journal of Production Research 52(22)(2014), 6760–6781.

[6] Sawik, T.: *Optimization of cost and service level in the presence of supply chain disruption risks: Single vs. multiple sourcing*, Computers & Operations Research 51(1)(2014) 11–20.

[7] Sawik, T.: *Selection of resilient supply portfolio under disruption risks*, Omega 41(2)(2013), 259–269.

[8] Yager, R.R.: *On ordered weighted averaging aggregation operators in multi criteria decision making. IEEE Transactions on Systems*, Man and Cybernetics 18(1988), 183–190.

[9] Kostreva, M.M., Ogryczak, W., Wierzbicki, A.: *Equitable aggregation and multiple criteria analysis.* European Journal of Operational Research 158(2004), 362–377.

[10] Sawik T.: *On the fair optimization of cost and customer service level in a supply chain under disruption risks*, Omega 53(2015), 58–66.

NEW PERSPECTIVES – DIGITALISATION TO ADVANCE PRODUCTION AND LOGISTICS NETWORK

Stefan SCHMIDT[1], Benjamin S.G. SCHMIDT[2]

[1]Process and Quality Management, University of Applied Sciences and **VWI**
Fritzstrasse 41, D-82140 Olching/Munich,
Germany
[2]Utrecht University, Faculty of Geosciences, Utrecht,
Netherlands

Abstract:

Companies are continuously optimising production and logistics processes at their plants, thereby drawing on the opportunities arising through digitalisation. Complex processes in production and logistics can be made even more efficient by applying new technologies. For automotive manufacturers, digitalisation opens up new perspectives with regard to the advancement of innovative and people-oriented production systems. This paper shows a case study of a German automotive manufacturer. An overview is given of the digitisation process used that is essential for production and logistics network, together with examples of self-driving robots in supply logistics, the first 40-ton electric truck/transport on city roads and innovative human-robot cooperation in production [1].

Keywords:

examples, self-driving robot, electric truck, factory digitalisation, human-robot cooperation

1. INTRODUCTION

This company is continuously optimising the production and logistics processes at its plants, thereby drawing on the opportunities arising through digitalisation. Complex processes in production and logistics can be made even more efficient by applying new technologies. For this German automotive manufacturer, digitalisation opens up new perspectives with regard to the advancement of innovative and people-oriented production systems. A state-of-the-art work environment provides a sustainable benefit to their workforce.

In turn, the freed potential in the production systems allows the company to respond even more individually to customers' wishes and to step up the flexibility of the production chain. The top priorities are reliable processes and high quality in production, which can both be facilitated by implementing digital technologies.

There are considerable benefits for the workers too. In the long term, these developments will modernize their work environment at the plants even further. Digitalisation gives new leeway and greater efficiency in some processes, which provides a sustainable benefit to their workforce. In the future, people in production will be creators of their work environment to an even greater extent than they are today. Furthermore, they will benefit from the declining share of physically strenuous tasks [1,2,3].

2. DIGITALISATION IS ESSENTIAL FOR PRODUCTION

When it comes to digitalisation, this German company focuses on 6 key areas in production and logistics [1].

2.1. Context-sensitive assistance systems

Intelligent tools can directly support staff in carrying out their tasks and also simplify complex processes. In a pilot project, two of the automobile manufacturer's German plants tested smart watches that alert workers when a car with special requirements is approaching. The display lights up and the vibration alarm is triggered, which act as a reminder to workers that the next process step requires, for instance, a different number of screws to be fitted, Figure 1.

2.2. Innovative robot systems

As a way to reduce the strain on workers, physically demanding and non-ergonomic tasks can now be carried out by innovative robot systems. Lightweight robots can work side by side with people without any safety fence; their application ensures the same high level of quality throughout, especially for repetitive and tedious tasks. As early as 2013, the company started to use lightweight robots for a variety of tasks, such as fixing the sound insulation to the inside of the doors under precise and steady high pressure or applying adhesive to windscreens, for example. Lightweight robots have been integrated into series production at the plants in US as well as in three German plants (see chapter 3.3.).

Figure 1 – Smartwatch supports assembly work [1]

2.3. Simulation and factory digitalisation

The use of digital data, in particular, offers great potential for raising efficiency in processes. The digital recording of a factory in 3D brings with it significant advantages compared to the two-dimensional, manualstandard approach. One example: it only took one weekend to measure the RR plant in the UK and to record it down to an accuracy of two Millimetres with a special 3D scanner and high-resolution digital cameras (see video). So, as a first, the site now has a threedimensional likeness of its production facility for planning purposes; the need for a laborious CAD reconstruction of actual structures and manual recording on-site is thus eliminated. Contrary to the traditional two-dimensional plans, any spatial change can now be intuitively simulated and assessed. The digitalisation provides a precise and comprehensive up-to-date database for quick and flexible adaptations in production, Figure 2.

Figure 2 – Simulation and Factory Digitalisation, plant the UK (2015) [1]

2.4. Planning and control systems

Automated data analyses lead to major progress in improving quality and efficiency. Especially in the parts provision process of the plants and the component production process, networked data can provide transparency in recording the flow of goods and even give specific information about the quality of the parts. At the company's two German plants, for instance, data matrix codes identify and record the entire production process of carbon parts for the new top premium series. In addition, the square, camera-readable bar code also includes information about the processing chain.

2.5. Smart logistics

On a larger scale, smart data technologies provide real-time information on the entire supply chain. In the event of problems arising on the transit route, the respective parts supply unit can respond immediately. These 'radar' functionalities increase the transparency in the company's international supply network and optimise supply chains.

2.6. Advanced analytics

Automated data analyses improve process safety at the company's plants. It is most of all the sum of many small measures that helps plants to optimize processes. For instance, when standard process curves are analysed, the data of an individual screw bonding process can be automatically structured and assessed. Deviations from the standards are immediately remedied before process disturbances occur. Thanks to the great number of application scenarios at the company production sites, efficiency and quality can be increased substantially.

Digitalisation offers a great potential when it comes to taking the production and logistics systems to the next level. However, not everything that is technically feasible also makes sense. The point is to consider the added benefit to the company – and this can best be done by our workers, who actively and continuously shape their production.

3. EXAMPLES OF ADVANCED TECHNOLOGIES IN PRODUCTION & LOGISTICS

3.1. Self-driving robots in supply logistics

The packaging plant supplies the company's international assembly and production sites with car parts. In the hall of supply logistics, a self-driving robot manoeuvres itself underneath a roller container with parts. Silently and with flashing lights, it picks up the container and begins to move through the logistics hall. The system is complicated and extensive and nobody can find their way around without a good sense ofdirection. However, this is no problem for the transport robot, which is about the size of a suitcase. Flanked by radio transmitters and equipped with a digital map, it drives independently to the destination of the goods. Should a tugger train cross its path, a fitted sensor identifies the obstacle and stops the self-driving robot, which is loaded with car parts weighing up to half a ton, Figure 3.

In terms of smart logistics, the company is promoting innovative and trend-setting logistics systems. The development of the Smart Transport Robot is an important milestone for the company with regard to the digitisation and autonomisation in production logistics. This innovation project makes an important contribution to the agility of the supply chain in logistics and production. It enables the supply chain to adapt to changing external conditions quickly and flexibly [1,4].

Figure 3 – Self-driving robots in supply logistics [1,4]

Measuring its distance to three radio transmitters allows the robot to calculate its exact position and route.

With the help of sensors, it identifies critical situations and can respond accordingly, sharing the route with people and other vehicles. When the innovation is implemented in series operation at a later point in time, a 3D camera system will make autonomous navigation in supply logistics even more accurate. The transport robot will be able to function without the floor-mounted induction loops for navigation and will move freely within the space. The battery-powered radio transmitters mounted to the walls of the hall can be expanded to further areas in logistics flexibly without major effort and at low costs.

For the company, a self-driving robot tailored to meet the demands of the company's logistics and production supply is a top priority. Besides custom-fit measurements for the containers to be transported, the vehicle also has sufficient battery capacity, as the developers have drawn on the experience gained with eautomobiles: batteries previously fitted in e-vehicles are being sustainably reused. This e-automobile battery module will provide eight hours' worth of energy, covering a full shift.

This pilot project is being transferred to series operations this year. The company has collaborated with the Fraunhofer Institute for this project. The collaboration under the label of the Company Enterprise Lab for Flexible Logistics was established in September 2015. It aims to explore future solutions for logistics areas. Initial findings have been presented at the trade fair LogiMAT 2016 in Stuttgart from March 8 to 10, 2016 [4], at the stand of the Fraunhofer IML as well as in the forum "New transport robots – agile, strong, versatile". In the future, the Smart Transport Robot can be deployed in both packing areas and in assembly logistics. This step in the automation simplifies the materials procurement process for workers in packing departments and reduces the supply space in the supermarket. The self-driving robot is being developed and tested at the company's Innovation Park. This centre is the logistics hub for material management and justin-sequence supply to the company sites in ten different countries. The Innovation Park is also home to the cockpit production for several plants.

3.2. First 40-ton electric truck for transport on city roads

The company is partnering with logistics company Scherm Group to deploy a 40-ton pure-electric truck in the city this summer and become the first automobile manufacturer in Germany to use an electric truck of this size to transport materials on public roads [1,5], Figure 4.

The innovative traction vehicle, which is licensed for use on public roads, will be deployed as of this summer for just-in-time material transport over short distances. The electric truck will drive between the logistics company Scherm Group and the company's plant in Munich eight times a day, covering a distance of almost two kilometres one-way. Thanks to its alternative drive train, the truck is quiet, CO2-free in traffic and generates virtually no particle pollution for the environment. This is also reflected in the vehicle's overall assessment in comparison with a truck with diesel engine: The environmentally friendly truck will generate 11.8 tons less CO_2 per year – equivalent to a middle class vehicle, with Efficient Dynamics, driving almost three times around the world.

Just under two years ago, the company's e-automobile put sustainable mobility on the road. This pure electric truck signals that they are constantly working on innovative solutions and tackling logistics challenges. The company is therefore delighted with the cooperation with Scherm Group.

Figure 4 – First 40-ton electric truck for transport on city roads – Quiet and environmentally friendly [1, 5]

The company and Scherm Group are investing a six-figure sum in the pilot project, which will initially span one year. If the vehicle proves itself in everyday driving conditions, both partners will seek to expand the project. After a long search, the two partners have found an electro-mobility solution for the transport sector. The Scherm Group is certain that, together with the automobile manufacturer, it will gain valuable
experience from this pilot project.

The company pursues a holistic approach that is focused on implementing sustainability throughout the value chain. In addition to future-oriented mobility solutions, issues such as corporate environmental protection, efficient use of resources and reduction of CO2 emissions are firmly rooted in company strategy. Since 2014, the company has sourced more than half of its global electricity needs from renewables.

Scherm Group is an international systems provider offering solutions for the logistics, transport, real estateand service sectors. As a provider of services for the entire value chain, the company employs a workforce of around 2,000 employees at 14 locations and on a mobile basis in around 500 company-owned trucks. Sustainability is an important factor the company has defined as a fundamental value.

3.3. Innovative human-robot cooperation in Production

At the automotive company’s US site, the future has already begun: In door assembly, people and robots work side by side – without a safety fence – in one team. The US plant is the first production facility worldwide that has succeeded in implementing direct human-robot cooperation in series production [1], Figure 5.

Four collaborative robots equip the insides of the doors of SUV models with sound and moisture insulation. In a first step, the foil with the adhesive bead is put in place and slightly pressed on by assembly line workers. Prior to the introduction of the new system, workers had carried out the fixing process with the aid of a manual roller. Today, systems with roller heads on robot arms handle this labour-intensive task that requires maximum precision. The sealing protects the electronics in the door and the entire vehicle interior against moisture.

The decision for introducing assembly robots in the US plant was based mainly on ergonomic considerations. Automation as a means to assist staff is particularly suitable for simple, highly repetitive work steps, which require considerable strength. Robots that assist production workers by assuming labourintensive tasks will characterize the factory of the future. Their benefits are strength and mechanical accuracy – and they perfectly complement the human attributes, flexibility, intelligence and sensitivity. Further company production sites are currently evaluating the possibility of unique collaborative robots.

The direct interaction of man and machine requires top safety standards, as the robots are placed in the direct vicinity of the workers without any protective devices. They run at a low speed within a defined environment and are stopped immediately in case their sensors detect an obstacle in their way.

Figure 5 – Innovative human-robot cooperation in production 6 [1]

Thanks to the fully automated process, the rolling power applied to the fixing process can be measured exactly. As a result, the processing quality can be monitored on a permanent basis. In the case that the robot's work process is interrupted unexpectedly, a worker repeats the additional fixing procedure manually – because safety is paramount.

The preliminary work for the future-oriented application of collaborative robots at the US site was developed over a period of two years. The project was carried out in close cooperation with the manufacturer of the robots, Universal Robot. The successful implementation of an ergonomically optimised human-robot cooperation in series production is a major step toward future automotive engineering and Industry 4.0 (IoT, Internet of Things). Collaborative robots enable the company to create new forms of design in the process layout. Further applications of collaborative robots in assembly are being evaluated; the roll-out of the existing facility at the other plants of the company's Production Network is currently in the planning stage.

4. SUMMARY / CONCLUSION

Some of the approaches currently under wider discussion as part of 'Industry 4.0' (IoT) have previously been introduced at the company or are in their rollout stage. For the company, Industry

4.0 (IoT) does not mean production without people and also not necessarily mean increasing automation. In this context, the main issue for the company is the reasonable application of new technologies to provide ideal support to the workers in production, logistics and production planning. Day-to-day work and skill levels of people in digital factories are different from today's traditional workers as shown in Figure 6 [6].

Besides the intelligent data management, the approach also includes sophisticated human-robot systems that can significantly improve ergonomically unfavourable work procedures. As the digital and the physical worlds grow closer together, new opportunities arise that allow people to cooperate more efficiently in the company's global production network. Mobile assistance systems will offer improved support to production and logistics workers in the future. In all these efforts, the focus is not on the technical feasibility, but on the specific benefit in production technologies that actually reach the end customer.

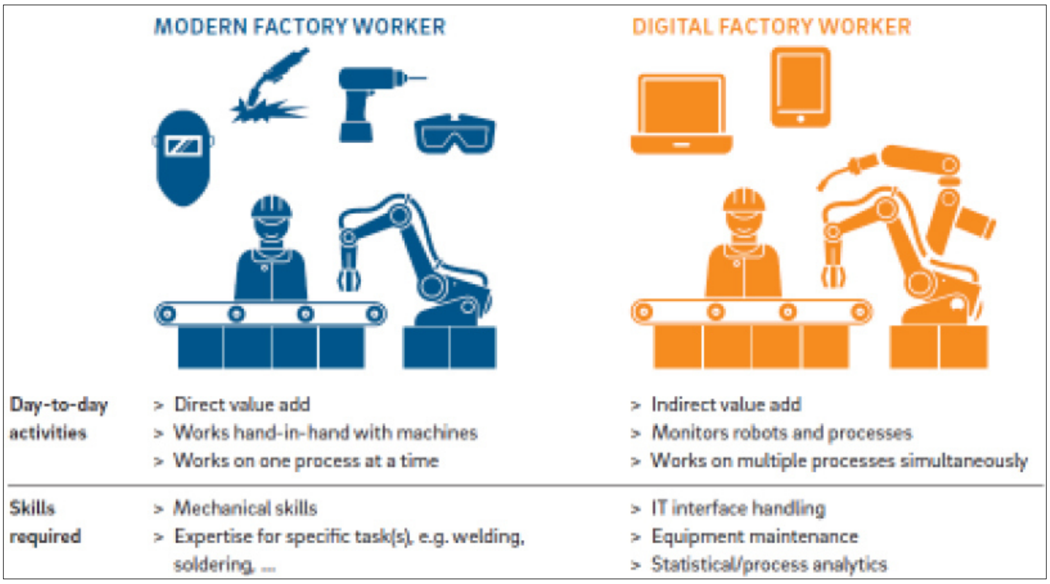


Figure 6 – The worker of tomorrow [6]

5. REFERENCES

[1] German Premium Automobile Manufacturer, Several Reports, Germany, 2014/15/16.

[2] Schmidt, S.: *Operational excellence – Weg zum nachhaltigen Weltklasse-Niveau*, Proceedings of Operational Excellence OPEX2015, Hamburg, March 2015.

[3] Schmidt, B. S. G.: *The sixth age: An automobile manufacturer prepares for an ageing work force*, Proceedings of 3rd MOTSP, Bol, Island Brac, Croatia, June 2011, March 2015.

[4] *Self-driving robot in Supply Logistics*, Presentation at the LogiMAT Fair in Stuttgart, Germany, Forum New transport robots – agile, strong, versatile, March 9, 2016.

[5] Scherm Group, SCHERM Holding & Verwaltungs GmbH, 85123 Karlskron, Germany, 2016.

[6] Reinhold, T. (ed.): *Digital factories – The renaissance of the U.S.* automotive industry, Roland Berger, Munich, 2016.

SOCIAL IMPACT OF RESTRICTIONS ON INVENTORY MANAGEMENT

Lucía M. SCHWARZ I.[2], Trina M. SCHWARZ I.[2], María J.GARCÍA G.[1], Gilberto J.HERNÁNDEZ G.[1], José G.HERNÁNDEZ R.[1]

[1]Minimax Consultores, C. A.
Urbanización El Bosque Chacaito, Caracas,
Venezuela
[2]Universidad Metropolitana.
Urbanización Terrazas del Ávila, Caracas,
Venezuela

Abstract

Inventory management is critical to business logistics. But if the state includes additional restrictions on its management cause disturbances with great social impact. To study the social impact of these additional restrictions, Logistic Model Based on Positions (LoMoBaP [MoLoBaC]), that studies the logistics through functions, will be used. In particular there will be used the Inventories models manager of the MoLoBaC. Hence the objective of this work: Determine the social impact that can cause government restrictions on inventory management, through the Inventories models manager of the Logistic Model Based on Positions.

Keywords:

Inventory models, Business logistics, Social impact, MoLoBaC, Government restrictions

1. INTRODUCTION

Inventory management is one of the most delicate tasks of logistics and business as a whole, by which appears frequently in the specialized literature, where is studied from different approaches: information (Cachon & Fisher [1]), finances (Michalsky [2]), reverse logistics (Toktay, Wein & Zenios [3]), integer programming in the oil industry (Lee et al. [4]), looking after risk aversion (Chen et al. [5]), taking into account multiple products and multiple processes (Mieghem & Rudi [6]), through simulation (Schwartz, Wang & Rivera [7]) and even with a vision of Sales and Operation Planning (S&OP) (Schwarz & Schwarz [8]). Inventory models of Operations Research focus on two fundamental aspects, when to acquiring and how much acquiring, since it is possible to see in many textbooks (Craven & Islam [9]; Hieller & Lieberman [10]; Stock & Lambert [11]; Taha [12]; Winston [13]). These models try to guarantee the companies that could support a balance between the offer and the demand. An excessive inventory is translated in costs and in vices in the productive processes; meanwhile a scarce inventory is translated in a disservice to the client, being both pernicious for the organizations.

To be the inventory management a fundamental aspect of the logistics, this has an impact on all of it, but at the same time the logistics has an impact on the entire organization, as discussed in García, Hernández & Hernández [14]; Guerrero et al. [15]; Hernández, García & Hernández [16,17]; Hernández et al. [18]; Jeney et al. [19] and in works quoted by them. From there that any disturbance that suffer the inventories will impact on the entire organization and at the same time customers of the same, affecting in this way the society as a whole.

Especially this disturbance in inventories can have worse consequences for the organization if they come from a law established by the government of the nation. In particular in the Bolivarian Republic of Venezuela there was approved a legislative decree that allows to judge the businessmen and owners of establishments for the crime of hoarding (Gaceta38862 [20]) and that in certain form is considered hoarding when high levels of inventories are had, especially if it involves products of regulated price. And in the case of price regulation that there is a law of the year 2003 (Gaceta37629 [21]), but that has been modified or adjusted over time, in particular with decree law of fair price in 2011 (Gaceta39715 [22]) and a law on the same topic, the fair prices, of 2014 (Gaceta40340 [23]). This situation of laws to prevent hoarding, based on the control of prices are not unique to Venezuela, there is also a similar law in Honduras (Gaceta32370 [24]). These documents most often have political objectives, by which business performance is not taken into account, which can have adverse consequences for production centers. If also have bullwhip effect as proposed in the well-known game of the beer (Barlas & Gunduz [25]; Bottani, Montanari & Volpi [26]) this impacts on society, bringing in the majority of the occasions scarcity and increase of prices, that are supposed aspects were expected combat. But the scarcity and excessive price rises at the same time bring high impact on society, all negative.

Moreover, the already mentioned high impact of logistics with almost all areas of an organization difficult its learning, for this have been created, in academia, four quantitative-qualitative models to facilitate its study (García, Hernández & Hernández [14]; Guerrero et al., [15]; Hernández, García & Hernández [16,17]; Hernández et al. [18]; Jeney et al., [19]). Each of these four models explain the logistics from a different point of view: the Logistics of Supply, Production, Distribution and Inverse Logistic (LSPDI, in Spanish el modelo Logístico de Abastecimiento, Producción, Distribución e Inversa [LAPDI]) focuses on logistics flows to analyze business logistics; the Logistic Model Based on Positions (LoMoBaP, in Spanish Modelo Logístico Basado en Cargos [MoLoBaC]) taking into account all the functions performed in positions related to business logistics; the Logistic Model Based on Indicators for Positions (LoMoBaIPo, in Spanish Modelo Logístico Basado en Indicadores de Cargos [MoLoBaICa]), somehow overlaps the MoLoBaC and analyzes the logistics through performance indicators and the Logistic, Strategic, Tactical, Operational with Inverse Logistics Model (STOILMo, in Spanish Modelo Logístico, Estratégico, Táctico, Operativo con logística Inversa [MoLETOI]), it is based on the three components of the administrative pyramid the: Strategic, Tactical and Operative and including reverse logistics, analyzes the business logistics. In this paper the interest will focus on the MoLoBaC and it will examine the impact of restrictions outside the organization that affect inventories, through its Inventories models manager (IMM). From there emerging the objective of this work: Determine the social impact that can cause government restrictions on inventory management, through the Inventories models manager of the Logistic Model Based on Positions. To achieve this overall objective will be included three specific objectives:
Show in that consist the Logistic Model Based on Positions.

To present the position Inventor models manager, emphasizing the functions that he redeems.

To take the functions of the Inventor models manager and own functions of Sales and Operation Planning, to discuss the impact that can cause government restrictions on the management of inventories of organizations.

With regard to limitations and scope, although will be based mainly on laws of the Bolivarian Republic of Venezuela, it will work hypothetically and as general as possible, to give the universal validity study.

1.1. Methodology

To achieve the general objective and specific objectives, it will make use of the Integrated-Adaptable Methodology for the development of Decision Support System (IAMDSS, in Spanish, Metodología Integradora-Adaptable para desarrollar Sistemas de Apoyo a las Decisiones [MIASAD]), which it was developed to create support systems, but for its flexibility adapts to different types of research (García, Hernández & Hernández [14]; Guerrero et al., [15]; Hernández, García & Hernández [16,17]; Hernández et al., [18]; Jeney et al., [19]; Schwarz & Schwarz[8]). MIASAD, as it outlined in this work, it faces the investigations without passing through the development of hypothesis; it follows a set of steps, which can be adapted to every situation, in particular. In this work, of form similar to the realized in the works previously mentioned it will be used: a) to define the problem that, as indicated in the objectives is determine the social impact that can cause government restrictions on inventory management, through the Inventories models manager (IMM) of the MoLoBaC; b) develop a first prototype, where, first of all, users of the final product are identified, in this case, because it is a scientific paper, its main readers will identify, which are all interested in studying the distortions that can be caused by government measures, to which they will be added logistics scholars from all aspects, especially those interested in the functions performed by those who have related positions to the logistics performance and in particular the interested in models and inventory management. Also the structure of the article is established, which in addition to this introduction will consist of two central chapters, in the first of them will present the IMM, especially through some of its functions and in the second chapter, which becomes the main of the work, it will be presented as one can make use of the functions of the IMM and the S&OP responsible for an organization, to illustrate the social impact that can have governmental measures affecting inventory management. The work closes with a chapter for conclusions and future research; c) search data, particularly on: S&OP, government regulations, social impact of logistics and about MoLoBaC, specifically the IMM; d) define alternatives, that consists of visualizing how there can measure the social impact of some governmental measurements using of the functions of the IMM and the responsible of S&OP; e) evaluate alternatives, taking as an element of evaluation, the feasibility of the proposed alternatives according to the established objectives; f) selecting the best alternative, as product of previous evaluation process, and based on the secondary objectives, tacit or explicit, being contemplated; g) implement the chosen alternative, that is to say establish all the mechanisms that allow the chosen alternative can be implemented and h) set controls or mechanisms to recognize that the chosen alternative remains valid in time.

In any case it is important to clarify that the alternative selected, can be a set of functions.

2. THE INVENTORIES MODELS MANAGER OF THE MOLOBAC

The Inventories models manager (IMM), in the Logistic Model Based on Positions (MoLoBaC), is the responsible for creating, implementing and control the use of all models for managing inventories that are used in the organization. This implies on the one hand a quantitative management of all aspects related to inventories, but both must have knowledge management systems and creating software for this purpose. But additionally it must be integrated with all positions in the organization and have a perfect knowledge from the same, to adapt the models created and often used, to the changing reality of the organization and the environment. But one should not think that the functions of IMM are subordinate to the requirements of other positions. On the contrary, it is necessary that the IMM complies with a lot of functions, some of them very complex and all varied, so that the company can achieve its main goal is simply to satisfy the end customer, without this means the sacrifice of many resources.

And this objective, satisfy the end client, requires, before entering to analyze the functions of the IMM, comment on a couple of concepts that are necessary to highlight, it is the business logistics and supply chain management.

As express Hernández, García & Hernández [16], the enterprise logistics is centered in searching and achieving a greater satisfaction, present and future of the final costumer, and includes socio-environmental and ethical-legal aspects, organization planning, execution and control of all related activities related to the attainment, flow, gathering and maintenance of materials, products and services, since the raw material source, including there the costumers through inverse logistics, to the sale point of the finished product local or international, massive or enterprise, in a more effective and efficient, maximizing performance and the expected quality, minimizing waste, times and costs and using modern information technologies.

Supply chain is a wider concept than enterprise logistics, in the sense of its scope and is understood as all the logistic aspects that must be synchronized among the producers of raw material, finished products and both wholesale and retail distributors, so the costumer is attended adequately satisfying its real needs; the logistic aspects in which Supply Chain Management (SCM) is usually centered are: warehouse, inventories, localization and transportation, but in order to achieve a good SCM it is required a high integration of the information systems (Hernández, García & Hernández [17]).

2.1. The functions of the Inventories models manager

The need to maintain satisfied to end customers, but at the same time not to incur an excessive use of resources, it obliges to the IMM to fulfill very effectively and efficiently with his functions, while, as already indicated, it must maintain a high interaction with many of the positions and areas of the organization. Some of the functions to be performed, the IMM are reflected in table 1, most of them taken based or inspired, among others, of Barlas & Gunduz [25]; Bottani, Montanari & Volpi [26]; Cachon & Fisher [1]; Chen et al. [5]; Michalsky [2]; Mieghem & Rudi [6], especially of Schwarz & Schwarz [8] and Hernández, García & Hernández [27], but mainly of García, Hernández & Hernández [28].

In table 1, will be used abbreviations such as IL by reverse logistics, IM by inventory models, IS&IR, by industrial safety and internal relations, Mg by manager, HM by handling materials, HR by Human Resources, R&D by Research and Development, S&OP by Sales and Operation Planning. Some of these abbreviations have already been used and these and some of the new will continue to be used in the rest of the work.

Table 1 – Some of the most important functions of the Inventories models manager

Intrinsic to the position	
01	Define the IM, which will be used in each case, throughout the organization.
02	Creating IM for the different items that handles the organization.
03	Ensure that all IM handled by the organization, are consistent.
04	Work for that without losing its consistency and robustness, the IM are as simple as possible.

05	Maximize customer service levels through the IM.
06	Establish general guidelines for the use of the IM.
07	Identify the IM more adequate for each one of the situations.
08	Incorporate the new experiences and lessons learned to the IM.
09	Develop models that allow to predict total breaks of inventories.
10	Maintain a constant review of the different IM that are used in the organization.
11	Work to achieve flexible IM that can quickly be adapted to changing situations.
12	Take care that the IM are sufficiently dynamic to react to scenarios that are not favorable.
13	Include in the flexibility of the IM the possibility of managing substitute products.
14	Incorporate the inventories of security in all IM used by the organization.
15	To promote the correct use of the different IM those are required in the organization.
16	Ensure that the results of IM are implemented in an appropriate manner.
17	Constantly review the IM, especially taking into account the profitability obtained.
18	Have a permanent control of the IM that are used in the organization.
19	Be informed of new technologies that may arise for making more efficient the IM.
20	Ensure that the premises that are used for each IM, are being met.
21	Take care that the IM used, in addition to responding to the costs, also guarantee the quality.
22	Contribute to establish the scope and area of applicability of each model.
23	Ensure that the IM can determine at all times the components that can become scarce for each product.
24	Ask, for each proposed IM, expert evaluation on their performance.
25	Keep informed all the organization of any change in the IM used.
26	Be persistent in the search for new ways of implementing the different IM.
27	Creating IM that are adapted to the needs of the different managers.
28	Generate IM, to help create products to market, without containing all its original components.
29	Review the results of the different IM used, to measure its effectiveness.
30	Adapt the IM to the purchasing power of consumers.
31	Participate to the entire organization, the results obtained by models that represent special situations.
32	Incorporate new tools and techniques to help improve the performance of the IM.
33	Help to interpret the results of any model, that a principle seems confusing.
34	Be in constant training for each time produce better IM.
35	Know the different Material Requirement Plan (MRP), the different final products of the organization.
36	Establish a clear classification of the IM according to its areas and possibilities of application.
37	Use the information obtained from the IM, to help prioritize the order in which customers will be served.
38	Ensure that the IM may predict rightly the obsolescence of components and products.
39	Constantly produce new IM and analyze its better applicability in the organization.
40	Investigate and contribute to the creation of new IM adapted to the organization.
41	Try to incorporate equipment, technologies and processes that improve the use and performance of IM.
42	To take care that the IM help to guarantee the safety of the organization.
43	To ensure the proper functioning of the equipment used to execute the IM.
44	Adapt the IM to the launch of new products, whether their own or of the competition.
45	To create systems those allow him to evaluate the proper performance and of his subordinates.
46	To ensure through the use of the IM, which help minimizes the penalties for late deliveries to

	customers.
47	Ensure that the staff of IM respects all safety rules, although this is not a dangerous task.
48	Constantly perform sensitivity analysis (what if?) with the IM, to cover any variation in the environment.
49	Distribute in the most equitable way possible, the daily workload.
50	Develop strategies that allow use IM to know the cycle and the lifetime of the organization.
51	Contribute in the S&OP of the organization helping, through the IM, to the coordination between: marketing, production, sales, finance, production and inventories.
52	Intervene in the formulation, approval and implementation of the plan of inventories of materials.
53	To take care so that the IM protect to the organization of the effect bullwhip.
54	To achieve that the IM contribute in all the aspects of the S&OP of the organization.
Related to other positions of MoLoBaC	
55	Analyze with all managers of MoLoBaC their needs for IM models.
56	Evaluate the prototypes of new IM to propose the remaining positions of MoLoBaC.
57	Facilitate the integration of the different IM that may be using different managers.
58	Support the Maintenance Mg and his subordinates through appropriate IM.
59	Adapt IM, with the help of Mg Procurement and their subordinates, delivery times of supplies.
60	To guarantee, with the help of the Mg of Quality, that the IM take in account the quality of the received supply.
61	To try, together with Procurement Mg and his subordinates, that the IM help to support the balance between the demand and the received provisions.
62	Request support from the Cost Mg, to the IM used tends to minimize costs.
63	Support the Finance Mg in the budgeting of the organization.
64	To use the results of the IM to give supported to the Location Mg, when it is necessary to establish a new installation.
65	Review, together to the R&D Mg and their subordinates, all new technologies that can contribute to generate best IM.
66	Work jointly with the managers of Inventories and Spare and equipment, for a better management of the inventories of the entire organization.
67	Help in their functions to the Orders processing Mg, through the IM.
68	Support the HM Mg through the IM.
69	Compare with the Stores Mg, that the actual values in warehouse, match the thrown by the models.
70	Provide the Marketing and sales Mg of individuals IM, for the control of promotional products.
71	Prepare, together to the HR Mg, the career plan and training courses of his staff.
72	To contribute, as a specialist in models, with the Forecast Mg, to prepare prediction models for the entire organization.
73	Creating IM especially directed to handle the products of IL.
74	Participate with the Projects Mg, in projects that improve the performance of the IM.
75	Help the Environmental Mg, to generate IM to help preserve the environment.
76	Try, together the IS&IR Mg that the IM, also contribute to the safety of the organization.
77	To use, together with the Customer service Mg, the IM to give a better service to the clients.
Related to MoLoBaICa, LAPDI, MoLETOI and the enterprise logistics in general	
78	Work through the IM, for the management of flows, in particular those of materials, as efficient as possible.
79	Help to have a better control of the flows of the organization through the IM.
80	Generate indicators that measure the performance of himself and his subordinates.

81	To improve through the IM the whole tactical performance and especially the operational one of the organization.
82	To do that the IM help in the vision, mission and guiding principles of the organization.
83	Contribute to fulfill the vision, mission, and guiding principles of the organization, through the IM.
84	Collaborate in the lost minimization of products and especially of time, through the IM.
85	Support via IM with those responsible for different positions in the company to comply with the strategic and tactical plans of the organization.
86	Adapt the IM of the organization to changing conditions in the environment.
Related to SCM and the enterprise and its environment as a whole	
87	Support providers through appropriate IM, to better serve the organization.
88	Be alert to changes in the economy that may affect the demands of certain products and with this the IM.
89	Create opportunities for improvements, through the IM, for the organization and all the SCM.
90	Share information generated by the IM, with all the SC, to minimize the bullwhip effect and improve inventory management.
91	Create IM so as to provide support to other members of the SCM.
92	Share with other members of the supply chain advancements in IM.
93	Generate IM, to help the preservation of resources, especially energy.
94	Use inventory models as a tool to support society, from the organization.

Although they could mention other functions, especially related to S&OP, which it is recommended to review the work of Schwarz & Schwarz (2015 [8]), with the large number of functions presented in table 1 it can see the importance of IMM, this allows one to think that can be measured, through these functions, the social consequences that may have government restrictions, that affect the handling of the inventories, that will be the appearance to cover in the next section.

3. IMM, S&OP AND SOCIAL IMPACT OF GOVERNMENT MEASURES AFFECTING INVENTORY MANAGEMENT

An aspect that influences directly the inventories is the demand. But the demand is an uncertain variable, that depends more of external factors to the organization, that to the organization itself, among these factors can be highlight the regulations and laws related to the sale of certain products (Schwarz & Schwarz [8]). Moreover, as suggested Schwarz & Schwarz [8] one of the important aspects of S&OP is the production plan (PP) of each of the items to be manufactured, where detailing the amounts and dates in which generate the production orders. So the S&OP tries to satisfy the PP of an efficient and profitable way, impelling, anticipating and managing actions to attend to the needs and restrictions that appear; have the inventory plan as a basis for materials purchase plan (MPP); plan the distribution requirements as are the warehouses, transport, reception in warehouses, personnel, among others and establish policies and basis for decision-making to minimize failures [8].

In their work Schwarz & Schwarz [8] found, different cases or causes that could hinder the S&OP, among them are: Delay in providing a supply, Impossibility to develop a feasible plan for the next period, Change of image, Change in presentation, Products or materials whose stock is near to expire, Product to be discontinued, Supply outside the organization policy: over-stock or sub-stock, Limitation on the capacity of suppliers, Launching new products, Promotions and other marketing activities, Storage requirements of materials, Temporary suspension of a product, Low turnover inventories and Restrictions on the operational capacity of the plant.

The Inventories models manager (IMM), work as part of the S&OP, to achieve that all these causes affect the least possible the selling of the organization, however a different situation arises when, additional, state incorporates restrictions, that affect the management of inventories.

In table 1, were reflected 94 functions of the IMM, that in one way or another, will help to fulfill the goals of S&OP and of the organization as a whole, but the problems or causes previously presented if it add restrictions on the part of the state, these operational plans are almost impossible to fulfill, as it can be deduced from the presented in table 2. As already it mentioned, not only the organization is subject to regulations and special laws, rather they are also its suppliers and providers of their suppliers, which increases the distortion. And if it is also added that the supply chain downstream, it is being affected by consumer demand, that start demanding products, to guarantee an apparent protection in sights of a future scarcity, it has a dual requirement on the organization, that can be summed up by saying that every time receives less inputs to the time that it is required a greater number of products.

The situation described in the previous paragraph makes collapse the system and the models of inventories, by very well intentioned and flexible that have been developed and implemented beginning to have failures. These failures increase the scarcity and with it the demand, opening this way a vicious circle, that every time is more difficult to close. To all these the society is affected, being forced to make purchases nerve and to spend much time unable to meet their needs.

To remedy this situation productive organizations are hands tied and can only resort to alternative plans, which not always can be executed of right form, given the uncertainty of the sources of supply and the pressure on the part of consumers.

In the table 2 shows a set of situations that can occur internally and handling in organizations, some of its consequences for society as a whole and in case of existing, there are mentioned the functions of the Inventories models manager (IMM), that could help in every situation.

Although in table 1 were presented 94 functions related with the IMM, it is not surprising that only 23 of them, while some repeated several times, be those who appear in the table 2, like possible helps to the presented abnormalities. And not surprising because just these disturbances are caused by government entities, which although they should always be taken into account as a stakeholder more, in this case are laws that do not obey at all to the economic environment of the company and in most cases not even the economic environment of the nation.

That is to say against these interventions, there are not many preventive measures that can be taken. In other words, this functions that are being presented as a possible aid, they are really an understatement, since the most they can do is help the organization to receive the negative impact latest, but they cannot do anything when the situation is consummated, especially when it cannot provide of supply. And as seen in table 2, to the affecting the organization at the end it affects society as a whole.

Of course an organization that has good inventory models (IM), surely it will be able to react earlier and the consequences of the restrictive measurements will feel much later and probably with a less pernicious impact. But when these types of measurements are supported in the time the impact will always come to the productive organizations.

In the table 2, to sorrow that can see that there is not much that to do to avoid the impact neither in the organization nor in the social thing, however the organizations should make efforts to not be in situations 1, 2 or 3. Therefore must make adjustments as early as possible, in order to execute actions that can make the impact of government restrictions in situations type 4 or 5, that in any case allow a certain margin of maneuver and cause minor negative impact both in the organization, and in the society as a whole.

Table 2 – Social impact of government measures that affect the inventories

Situation	Consequences for the organization and society and possible ways to face them	IMM functions that could help
There is not supply.	1. Stop producing. Would lead to the bankruptcy of the company, leave without employment a group of workers, there would be had a source less of supplying of the products of this organization. It would cause large monetary losses to the shareholders.	01, 07, 09, 12, 31, 48, 50, 72, 86
	2. To stop producing temporarily until it is possible to have inputs. It would be an uncertain situation where it is generally dependent on third parties. Temporarily, there would be had a source less of supplying and it could have lost of employments, but if the shortage is extended, it would have the same consequences as in 1 and always with a loss to the shareholders.	02, 07, 08, 09, 10, 11, 12, 31, 48, 59, 86
	3. Remove products in inventory. Although the company is not able to produce any of its usual products, might have in inventory of some raw materials and packaging and even semi-finished products, which can no longer use and of which should get rid. In the best case they could be sold to competing companies or to third on different and low markets, generally with losses of money. For the society, in the end, there would be had the same consequences as in 1.	02, 07, 09, 10, 12, 23, 31, 38, 48, 86
Insufficient supplies of some products.	4. To prepare different products. In general these products would be an incomplete version of the originals, where some of the components they would not be present. Sectors of society could see strongly affected, since the eliminated product constituted part of their daily use, it is the case of children and elders, that require fortified products or defatted or with special conditions. In the organization are necessary changes, especially in the production lines and in the packaging. It could lead to job losses and even monetary losses, since, in general the company is reduced.	02, 07, 08, 09, 10, 11, 12, 14, 23, 28, 31, 35, 48, 61, 81, 86, 87
	5. Change of products. The new products would be modified versions of existing products, where some of its components would be replaced. Just as in 4, some sectors of society could be affected because the new products cannot fit in their daily use, for the rest of society there must be a process of adaptation to the new products. As in 4, the organization must make internal changes and again there may be job losses and monetary losses.	02, 07, 08, 09, 10, 11, 12, 13, 23, 28, 31, 35, 48, 61, 81, 86, 87
	6. To change branch completely. The company is dedicated to producing new products, which can be very different from their usual lines. In general, this usually leads to a forced reduction of the company, causing losses of positions of works and monetary. For society as a whole loses a source of supply of the original products, which could be basic, at least for some sectors. At the end, from the point of view of the original products, it is possible to come to a situation similar to the 1.	02, 07, 09, 10, 11, 12, 31, 48, 61, 81, 86, 87
	7. Get rid of inventories. Although the organization can handle a situation type 4 or Type 5, there will still be complementary products that will not be able to integrate the new production lines, so they must be rid of them, staying in a situation equal to 3.	02, 07, 09, 10, 12, 23, 31, 38, 48, 61, 86

With these latest observations can be passed to present some conclusions and to comment on possible lines of future research.

4. CONCLUSIONS AND FUTURE RESEARCHS

In the table 1 there appeared 94 functions of the Inventories models manager (IMM), which would help the organization in a good performance. Among these functions, some of them are intrinsically associated with the Sales and Operation Planning (S&OP). When listing these functions is well covered one of the objectives of this work.

On the other hand in the table 2 show seven cases in which it is possible to see the organization involved, to governmental laws appear that one way or another not allow free inventory management. These cases can be alleviated slightly with good management of inventory models (IM), applying some of the functions of table 1, but in reality, of the situation continued for a long period, there will be no chance to get ahead.

The previous thing allows to conclude that, in general, the laws that of one or another form they affect the handling of the inventories of the productive organizations, not going to achieve a social progress, but on the contrary they will have a negative impact, not only in the company, but in the society as a whole. And unfortunately, most of the consequences of these laws, it does not go to exist way of being able to handle them from the company, since in general they generate an effect bullwhip, that makes the situation more and more critical.

Although from the point of view of the inventories, it had not a happy ending, in the handling of laws that they interfere with the productive processes and the logistics, it is recommended to keep on studying this topic from other areas of the managerial logistics, to see if there are any of them, can offer some palliative to the organizations and the society as a whole.

5. REFERENCES

[1] Cachon, G.P., M. Fisher: *Supply chain inventory management and the value of shared information*, Management Science 46(8)(2000), 1032–1048.

[2] Michalsky G.: *Corporate inventory management with value maximization in view*, Zemedelska Ekonomika-Praha, 54(5)(2008), 187–192.

[3] Toktay L.B, Wein M.L., Zenios S.A.: *Inventory management of remanufacturable products*, Management Science 46(11)(2000), 1412–1426.

[4] Lee, H., J. M. Pinto, I. E. Grossmann, S. Park: *Mixed-integer linear programming model for refinery short-term scheduling of crude oil unloading with inventory management*, Industrial & Engineering Chemistry Research 35(5)(1996), 1630–1641.

[5] Chen, X., Sim M., Simchi-Levi D., Sun P.: *Risk aversion in inventory management*, Operations Research 55(5)(2007), 828–842.

[6] Mieghem, J.A.V., Rudi N.: *Newsvendor networks: Inventory management and capacity investment with discretionary activities*, Manufacturing & Service Operations Management 4(4)(2002), 313–335.

[7] Schwartz, J.D., Wang W., Rivera D.E.: *Simulation-based optimization of process control policies for inventory management in supply chains*, Automatica 42(2006), 1311–1320.

[8] Schwarz, L. M., Schwarz T.M.: *Propuesta de modelo de toma de decisiones en la planificación de ventas y operaciones de empresas Venezolanas de consumo masivo*, Production Engineering dissertation, Universidad Metropolitana, Caracas, Venezuela 2015.

[9] Craven, B.D., Islam S.M.N.: *Operations Research methods: Related production, distribution, and inventory management applications*, The Icfai University Press, India 2006.

[10] Hieller, F.S., Lieberman G.J.: *Introduction to Operations Research*, McGraw-Hill, USA 2001.

[11] Stock, J.R., Lambert D.M.: *Strategic logistics management*, McGraw Hill/Irwin, Boston, MA 2001.

[12] Taha, H.A.: *Operations Research: An introduction*, Pearson PrenticeHall, USA 2007.

[13] Winston, W.L.: *Operations Research. Applications and Algorithms*, Thomson: Canada 2004.

[14] García, M. J., G. J. Hernández,, J. G. Hernández: *Management indicators for Human resources manager of the MoLoBaC,* In N. Delener (Ed), GBATA Reading Book 2014, GBATA: USA, (2014), 193–200.

[15] Guerrero M., L.E., Hernández G. G.J., García G. M.J., Hernández R. J.G.: *Indicators and the Picking manager of the Logistic Model Based on positions,* In G. Dukic (Ed.), Proceedings ICIL 2014, University Zagreb: Croatia 2014, 273–282.

[16] Hernández R., J.G., García G. M.J., Hernández G. G.J.: *Logistics, Marketing and Knowledge Management in the Community of Consumers*, S. Buckley, G. Majewski, A. Giannakopoulos (Eds.), Organizational Knowledge Facilitation through Communities of Practice in Emerging Markets. IGI Global: USA 2016, 245–270.

[17] Hernández R., J.G., García G. M.J., Hernández G. G.J.: *Enterprise diagnosis and the Environmental manager of LoMoBaP*, Journal of Global Business and Technology, 12(1)(2016), 60–76.

[18] Hernández G., J.J., García G. M.J., Hernández G. G.J., Hernández R. J.G.: *Fantastic sports and the Research and Development manager of the Logistic Model Based on positions,* In G. Dukic (Ed.), Proceedings ICIL 2014, University Zagreb: Croatia 2014, 250–257.

[19] Jeney, A., Hernández J.G., García M.J., Hernández G.J.: *Generation and Knowledge Management System Through the information and networks manager,* In N. Delener (Ed.), GBATA Reading Book 2015, GBATA: USA 2015, 244–251.

[20] Gaceta38862: Gaceta Oficial de la Republica Bolivariana de Venezuela, Caracas, 31 enero 2008.

[21] Gaceta37629: Gaceta Oficial de la Republica Bolivariana de Venezuela, Caracas, 11 febrero 2003.

[22] Gaceta39715: Gaceta Oficial de la Republica Bolivariana de Venezuela, Caracas, 18 julio 2011.

[23] Gaceta40340: Gaceta Oficial de la Republica Bolivariana de Venezuela, Caracas, 23 enero 2014.

[24] Gaceta32370: La Gaceta Republica de Honduras, Tegucigalpa, 19 noviembre 2010.

[25] Barlas, Y., Gunduz B: *Demand forecasting and sharing strategies to reduce fluctuations and the bullwhip effect in supply chains*, Journal of the Operational Research Society 62(2011), 458–473.

[26] Bottani, E., Montanari R., Volpi A.: *The impact of RFID and EPC network on the bullwhip effect in the Italian FMCG supply chain*, International Journal of Production Economics 124(2)(2010), 426–432.

[27] Hernández R., J.G., García G. M.J., Hernández G. G.J.: *Teaching Enterprise logistics through indicators: Dispatch manager*, K. Grzybowska (Ed.), 7th Scientific Conference 'Economy and Efficiency – contemporary solutions in logistics and production', Poznan, Poland 2013, 7–24.

[28] García G., M.J., Hernández G. G.J., Hernández R. J.G.: *Logística empresarial, un eslabón más para la paz social. Tres visiones*, documento presentado en la LXIV Convención Anual de la AsoVAC, Caracas, 20 noviembre 2014.

E-LOGISTICS AS PREREQUISITE OF E-RETAILING

Zdenko SEGETLIJA[1], Josip MESARIĆ[1], Davor DUJAK[1]

[1]Josip Juraj Strossmayer University of Osijek, Faculty of Economics
Trg Ljudevita Gaja 7, Osijek,
Croatia

Abstract:

Paper proceeds from the modern trends in retail: the stagnation of sales in the so-called. stationary retail and rapid sales growth in e-retail, and emphasizes the need for more accelerate development of e-logistics. E-logistics is becoming increasingly important, because in addition to businesses run solely through online store, many enterprises complement their stationary store with the online shop as a new sales channel. Concepts of e-logistics allow new competitors from countries that joined the European Union easier access to so far less accessible markets, while at the same time pressure on their domicile markets is growing and their trade and logistics companies are becoming vulnerable. Incorporating in the supply chains would positively affect companies from these countries by mitigating the contradiction of economies of scale and the economies of scope.

Keywords:

e-logistics, e-retailing, logistics service operators, EU, transition countries.

1. INTRODUCTION

Retail companies are constantly gaining in importance, because their expansion generates development of entire supply chains. Deployment of e-commerce, and related to this the development of e-logistics, is vital for the creation of their developmental strategies. In fact, recent years have been observed stagnation of sales in the so-called stationary retail and sharp development of e-retailing. Therefore, this paper analyzes the possibilities of e-retail and e-logistics offered to retail companies. Analysis was carried out for 16 European countries: Austria, Finland, Greece, Italy, Germany, Portugal, Spain, United Kingdom, Bulgaria, Slovakia, Estonia, Croatia, Hungary, Poland, Romania, and Slovenia. Special attention is paid to European transition countries (last 8) because new possibilities for expansion into new markets for their retail and logistics companies, and in the same time growing competitive pressure on their domestic market.

Development of e-retailing and e-logistics is analyzed based on the available literature and data from Eurostat. The contribution of the paper is to obtain new insights on the importance of distributive trade (especially e-retail and e-logistics) in the national economy. At the same time, paper constitutes only a basis for further research.

2. RETAILING, E-RETAILING AND E-LOGISTICS

It has long been pointed out that in developed market economies revolutionary changes occurs in the organization and functioning of retailing. These changes are result of overall changes in the retail environment. Therefore, retailing is rated as most dynamic phenomena in the distribution channel [1].

According to Levy and Weitz [2] retailing is "the set of business activities that adds value to the products and services sold to consumers for their personal or family use". However, for statistical monitoring is an important definition of retailing as a component of distributive trade. According to Eurostat [3;] overall distributive trade (Section G – Wholesale and retail trade; repair of motor vehicles and motorcycles), consist of:

- division 45 (wholesale and retail trade and repair of motor vehicles and motorcycles);
- division 46 (wholesale trade except of motor vehicles and motorcycles);
- division 47 (retail trade except of motor vehicles and motorcycles).

Eurostat [3] defines retailing as "the resale (sale without transformation) of new and used goods mainly to the general public for personal or household consumption or utilization, in shops, department stores, stalls, mail-order houses, door-to-door sales persons, hawkers, consumer cooperatives, auction houses etc."

Retail and wholesale are components of distribution channels and marketing channels. Marketing channels are all those organizations that product must pass between their production and consumption [4]. In the system of so-called consumer marketing channels there are following levels: manufacturer, wholesaler, jobber, retailer [4].

The subjects of analysis in this paper are companies engaged in distributive trade (especially retailing) and other companies (particularly parcel delivery service companies) participating in the distribution flow. The flows in the marketing channel can be [4,5]: (a) the physical flow; (b) flow of nomination (of ownership); (c) flow of payments; (d) the flow of information; (e) flow of promotions. Since business logistics is oriented to flows of goods and information within the company [6], but also outside the company [7], it is an important prerequisite for the successful operation of retail companies.

Among the activities regarding logistics services, transport and storage are of special interest. The division of the total activities of transportation and storage, according to Eurostat [3], has the following:

- division 49 (land transport and transport via pipelines);
- division 50 (water transport);
- division 51 (air transport);
- division 52 (warehousing and support activities for transportation);
- division 53 (postal and courier activities).

To understand the importance of the development of new logistics service companies for e-retailers, the paper will specifically examine Division 53 – postal and courier activities. According to Eurostat [3] this division includes: "postal and courier activities, such as pickup, transport and delivery of letters and parcels under various arrangements. Local delivery and messenger services are also included".

Based on the development of concentration in retailing were created large retail chains, which can be defined like this [2]: "A retail chain is a company that operates multiple retail units under common ownership and usually has centralized decision making for defining and implementing its strategy. Retail chains can range in size from a drugstore with two stores to retailers with thousands of stores, such as Safeway, Wal Mart, Target, and JC Penney. Some retail chains are divisions of larger corporations or holding companies".

The progress of the process of concentration is seen in the growing market share of a smaller number of companies [8]. The importance of the concentration in the retail is first in the fact that only large retail companies can use the achievements of modern technological progress and pursue development. Therefore, the concentration of retail is not only a result of its previous development, but also a condition for future development.

E-retail or Internet retail (which can also be called “online retailing”, “electronic retailing” and “e-tailing”) is a retail channel in which the offering of products and services for sale and communication with consumers performs over the Internet [2].

Statistically, the e-retail is monitored together with retailing via shipments/mail. In fact, retailing, not done in stores, stalls, markets and fairs, would be one that is done on the basis of orders by mail or through the Internet. According to Eurostat [3] “This class includes retail sale activities via mail order houses or via Internet, i.e. retail sale activities where the buyer makes his choice on the basis of advertisements, catalogues, information provided on a website, models or any other means of advertising and places his order by mail, phone or over the Internet (usually through special means provided by a website). The products purchased can be either directly downloaded from the Internet or physically delivered to the customer”.

Since the e-logistics develops in the flow of goods in modern conditions of e-business, it is important not only for Internet retailers, but also for so-called stationary retailers (retail in the store with a solid location).

According to M. Reindl and G. Oberniedermaiera [9] e-logistics, in the shortest way, can be defined as “logistics systems and processes in the Internet age”.

Naturally, e-retail and e-logistics are an integral part of e-business. In addition, e-retail is component of e-commerce, and e-logistics stands between e-commerce and e-procurement [10].

E-logistics has special role in integration of supply chain, elimination of intermediaries (wholesalers and retailers), and in the emergence and development of new logistics service providers. This is a way for traditional supply chains to adapt to requirements of *e-business* [11].

Contemporary supply chain management (SCM) is enabled by development of information and communication technologies (ICT). Therefore, analysis of marketing channels has been replaced by analysis of whole supply (or logistics) chains. The reason is emergence of different conceptions of companies cooperation related to flows in whole economy – from manufacturer of first raw materials, over all levels of production and distribution to consumption. Supply chain consists of series of activity and organizations that carry out materials on their journey from initial suppliers to the final customer [12].

It is important to stress that e-logistics enables economical shaping of planning, conducting and control of logistics tasks through usage of internet technologies, improvement of logistics service and intensifies cooperation between logistics partners in supply chain. Accept integration of internets systems in existing ICT system, precondition for implementation of e-logistics is further development of organizational flows and processes, as well as clear guidance of all members of supply chain to overcome information barriers between companies [10].

For logistics used by e-retailing, it is important to point out that parcel delivery is used, which are shipped to final customer either directly from the manufacturer's warehouse or via cross – dock warehouses [13].

3. VERTICAL ALLIANCES AND SUPPLY CHAINS

Contemporary concentration processes and development of ICT contribute to vertical and horizontal connecting of entities-companies in marketing channels, and the entire supply chain.

3.1. Vertical and horizontal alliances

It is known that each marketing channel participants, thanks to its size and power, can take over the functions of other participants. Thus, vertical marketing systems are developed in special competitive circumstances, and they exist besides conventional [14]. This is an expansion of activities within individual corporations or groups, as well as the development of cooperative forms of independent companies.

In this way, large retail companies could also take over wholesale trade functions, and came in a position to dictate prices to production companies. It can be said that concentration of functions is developing, i.e. taking over functions of wholesale and production by retail companies, or groups [15]. Also, result of these processes of concentration is development of retail private labels. Concentration of procurement function enables "demand power" of retailers in relations to its suppliers.

Except vertical marketing system, in modern economies today there are also horizontal and multi-channel marketing systems, and increasingly important become hybrid marketing channels and multichannel retailing, since the use of only one channel is often not efficient enough. Companies form various channels for customers of different sizes [5]. This is a way of developing multichannel management [16] – It is the use of more sales paths available, i.e. the parallel use of multiple sales channels.

Analysis of development of marketing channel system found existence of [17]: (a) single channeling; (b) multi channeling; (c) cross channeling; (d) omni channeling. Multi channeling, cross channeling and omni channeling systems are connected with e-retailing and its accelerated development.

Whole supply chain is of huge importance for a company – both upstream and downstream partners (suppliers, intermediaries, intermediary's clients) create overall value networks [4]. This means that success in the market can be ensured only through the creation of the entire value network, not just by the downstream part-distribution channels. Therefore, large companies or groups, today manage their value added chain. Therefore, supply chain management can be viewed as a value chain management. Namely, the term "value chain" derived from Michael Porter, is often replaced by the term "supply chain" (Supply Chain) [18].

Supply chain is seen as a "transparent" value chain [9] – set of activities and relationships in the supply chain that maximizes value for the customer and achieve sustainable competitive advantage [19].

3.2. Significance of large retail chains and e-logistics

Large retail chains are becoming increasingly important as they take over role of managing supply chains, especially in "grocery" sector [20]. When large retailer (retail chain) dominates in supply chain, terms *retail supply chain* can be used. Balance in cooperation is changing due to processes of internationalization and consolidation of retailers and manufacturers. Retailers have expanded into new areas such as banking, insurance and catering services; but also the new operators entered the retail area [21].

Retailing is integrator of different value creations chains based on its retail assortment made of different products and services. At the same time, retail uses outsourcing to integrate different services (services of logistics service providers, banking services, internet services, etc.).

Supply chain management is especially important for retail company due to its position in distribution channel – in direct contact with consumers. Retail company uses it to increase strategic advantages, as it improves product availability and inventory turnover, which creates a higher rate of return on assets [2].

Significance of large international retail chains can be observed in its appearance in some countries (outside country of origin) in which they perform through its private labels and its own retail brand, build logistics and distribution centers, and (usually) bypass local production due to the large quantities purchased at low prices [23]. However, the expansion of international retailers from developed countries to less developed countries (e.g. transition) creates competition that suppresses domicile manufacturers and retailers off the market.

Large retail chains acting internationally can integrate all levels ahead of them (manufacturers and market intermediaries) and consequently direct and develop the production itself. In addition, they have concentrated functions, allowing not only to be larger in size but also to have stronger market impact than indigenous retailers in different countries [24].

European retailing in most countries in early 1990s came into a phase of stagnation, which shift their business to the following trends [25]:

- rapidly evolving retail formats with the concept of low prices (notably discounters that offer a modest range, but with high proportions of products with its own brand – private labels);
- the largest retailers continue to increase their market shares (further growth of concentration);
- the trend toward globalization.

The latest trends in developed countries show the stagnation of sales turnover in the so-called. stationary retailing and a sharp increase in turnover in e-retail. In eight economic- and market-developed European countries e-retailing in 2015 rose by 18.6% and it's reached shares in total retail sales in 2015 were: United Kingdom 15.2%, Germany 11.6%, France 8.0%, Sweden 7.8%, Netherlands 7.4%, Spain 3.5%, Poland 3.3%, Italy 2.1% [26]. It is therefore considered that the e-retailing represents special challenge for transition countries, i.e. new EU member countries.

Such development leads to increased competition between local and online retail. But the future brings intensifying of competition within the online retailing itself, between online retailers from different countries. In the European Union, according to a study by the EU Commission, online cross-borders e-sales in 2014 amounted to over 16% of the total online shopping in EU [27].

In any case, e-retailing and e-logistics a represent a major challenge. It can be concluded that retailers who are currently operating in the so-called. stationary stores, in the future have to accept the idea of cross-channeling. For sustaining in the market it will not be enough to enter area of the online retailing, but also intelligent merging of online retailing and stationary stores will be needed [28].

4. ANALYSIS OF SELECTED INDICATORS

Table 1 presents data of retail trade turnover (division 47) and turnover via mail orders to house and via Internet in selected European countries in 2013.

Table 1 – Turnover in retailing (division 47) – in total and via mail orders to house and via Internet in selected European countries in 2013 (source: annual detailed enterprise statistics for trade (NACE Rev. 2 G), Eurostat, 2016; *P* – provisional)

Ordinal	Country	Turnover in mil. EUR		Share of turnover via mail order houses or Internet (in%)
		Retail trade - division 47	Via mail order houses or via Internet	
1.	Austria	60.363,2	1.338,2	2.22
2.	Finland	38.566,7[P]	394,6	1.02
3.	Greece	45.874,9	228,7	0.50
4.	Italy	307.704,6	3.753,2	1.22
5.	Germany	491.732,1	30.739,6	6.25
6.	Portugal	43.110,4	152.9	0.38
7.	Spain	204.932,1	1.665.2	0.81
8.	United Kingdom	422.904,1	22.437,8	5.31
9.	Bulgaria	11.541,3	119,7	1.04
10.	Slovakia	17.039,8	126,8	0.44
11.	Estonia	5.783,0	131,3	2.27
12.	Croatia	12.197,1	62,6	0.51
13.	Hungary	25.402,4	295,8	1.16
14.	Poland	102.543,3	2.734,9	2.67
15.	Romania	32.724,4	572.9	1.75
16.	Slovenia	12.010,2	173,1	1.44

If we consider only retailing of goods of companies whose main activity is retailing, shares of e-retailing are lower than the shares of e-retailing in the total retail sales [26]. In this case, among the 16 surveyed countries, the best results achieved German retailers.

In accordance with data on retail shares by mail and the Internet in total retailing (division 47) are the data about the relationship of the turnover of postal and courier services (division 53) and total retail sales (Table 2).

Further analysis of the postal, parcel and courier services should take into account not only the development of e-retailing, but also development of parcel delivery services market

Table 2 – Relations between value of postal and courier services (division 53) and retailing turnover (division 47) in selected European countries in 2013
(source: annual detailed enterprise statistics for trade (NACE Rev. 2 G), Eurostat 2016; Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95), Eurostat 2016; * estimated, 2014; **2011)

Ordinal	Country	Transportation and storage - turnover in mil. EUR		Relation 53:47 in%
		Retail trade – division 47	Postal and courier activities – division 53	
1.	Austria	60.363,2	2.613,3	4,33
2.	Finland*	37.960,5	1.554,6	4,10
3.	Greece	45.874,9	684,9	1,49
4.	Italy	307.704,6	9.795,3	3,18
5.	Germany	491.732,1	28.383,9	5,77
6.	Portugal	43.110,4	878,3	2,04
7.	Spain	204.932,1	4.032,5	1,97
8.	United Kingdom	422.904,1	25.996,1	6,15
9.	Bulgaria	11.541,3	269,5	2,33
10.	Slovakia	17.039,8	551,7	3,24
11.	Estonia	5.783,0	91,7	1,59
12.	Croatia**	11.892,4	272,0	2,29
13.	Hungary	25.402,4	829,4	3,27
14.	Poland	102.543,3	1.965.2	1,91
15.	Romania	32.724,4	650,1	1,99
16.	Slovenia	12.010,2	293,6	2,44

5. CONCLUSION

The paper indicated current trends in distribution channels and supply chains in developed market economies, and increased importance of e-business and – as its part – e-retailing and e-logistics. E-retail is a challenge for countries in transition, because in the supply chain can participate new service providers (logistics and others), and as this could alleviate the contradiction of economies of scale and economies of scope, causing their company's risk in domestic markets.

Conducted analysis, however, indicates that the observed transition countries currently lagging behind in the development of e-retailing and the application of modern ICT. But the prospects are in the faster development of the service providers of parcels delivery within the modern e-logistics.

6. REFERENCES

[1] Berkowitz, E.N., et al.: *Marketing*, Fifth Edition, Irwin, McGraw-Hill, Boston a.o., 1997.

[2] Levy, M.L., Weitz B.A.: *Retailing Management*, Eighth Edition, MxGraw.Hill, Irwin, New York 2012.

[3] *Statistical classification of economic activities in the European Community*, Eurostat. NACE Rev.2 2008, http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF/dd5443f5-b886-40e4-920d-9df03590ff91?version=1.0, 2016-04-28.

[4] Kotler, P., et al.: *Principles of Marketing*, 10th Edition, Prentice-Hall, 2003. European Edition, Pearson Education Ltd. 2005, Croatian Translation, MATE, Zagreb, 2006.
[5] Kotler P., Keller K.L.: *Marketing Management,* 12th Edition, Pearson Education Inc., Prentice-Hall, 2006, Translated in Croatian, MATE, Zagreb, 2008.
[6] Rupper, P.: *Logistik – Eine neue Unternehmensdimension,* In: *Unternehmenslogistik*, P. Rupper (Hrsg.), Verlag Industrielle Organisation, Zürich, und TÜV, Rheinland, Köln, 1991, 1–23.
[7] Straube, F.: *Logistik Management,* Vorlesung, Bereich Logistik, Grundlagen und Trends der Logistik, Bereich Logistik, TU Berlin 2008, http://www.logistik.tu-berlin.de/uploads/media/01.VL_Logistik_Management_SS08_Einf_hrung_in_die_Logistik.pdf, 2016-04-28.
[8] Konzentration im Einzelhandel, http://www.mein-wirtschaftslexikon.de/k/konzentration- im-einzelhandel.php, 2015-04-28.
[9] Reindl, M., Oberniedermaier G.: *eLogistics*, München: Addison-Wesley, München 2002.
[10] Krieger, W.: *E-Logistik*, Gabler Wirtschaftslexikon, http://wirtschaftslexikon.gabler.de/ Definition/e-logistik.htm, 2016-04-15.
[11] Groznik, A.: *E-Logistics: Informatization of Slovenian Transport Logistics Cluster*, Management, 10(1)(2005), 93–105, https://www.efst.hr/management/.../5-groznik.doc, 2016-04-15.
[12] Waters, D.: Logistics: *An Introduction to Supply Chain Maanagement*, Palgrave Macmillan, New York, 2003.
[13] Groß, W., et al.: *Logistik im deutschen Groß- und –einzelhandel. Herausforderungen* und Trends, 31. Deutscher Logistik Kongress, 22–24 Oktober, 2014, 330–372, www.bvl.de/misc/filePush.php?id=27318...E1, 2016-04-15.
[14] Koppers, L.; Klumpp, M.: *Kooperationskonzepte in der Logistik - Synopse zu SCM, ECR und VM*, FOM Hochschule für Oekonomie & Management, Institut für Logistik- & Dienstleistungsmanagement, Schriftenreihe Logistikforschung, Band 9, April 2010, Essen, http://www.fom.de/download/189-Band9_02.pdf, 2014-03-24.
[15] Segetlija, Z.: *Koncentracija funkcija i transparentnost tržišta – odlučujući čimbenici oblikovanja maloprodajnih poslovnih jedinica* [Concentration of Functions and Transparency of Markets – Decisive Factors for Formating Retail Business Units], Proceedings of 11th Scientific Conference Business Logistics in Modern Management, Segetlija, Z.; Karić, M. (Ed.), Osijek 2011, 187–201.
[16] *Multi-Channel-Management,* http://www.ecc-handel.de/multi-channel-management.php, 2011-04-12.
[17] Haderlein, A.: *Die digitale Zukunft des stationären Handels*, MI 2012, mi-witschaftbuch Verlag, Münchner Verlagsgruppe GmbH, München, http://ideennetz.dynalias.org/kride/fileadmin/dokumente/veroeffentlichungen/978-3-86880-138-5.pdf, 2016-04-28.
[18] Ayers, J.B., Odegaard. M.A.: *Retail Supply Chain Management,* Auerbach Publications, Taylor & Francis Group, New York–London, 2008.
[19] Bozarth, C.C., Handfield R.B.: *Introduction to Operations and Supply Chain Management*: Pearson Education Inc., New Jersey, Upper Sadle River 2006.
[20] Dujak, D.: *Uloga maloprodaje u upravljanju opskrbnim lancem* [Role od Retail Trade in Supply Chain Management], Doctoral Dissertation, J.J. Strossmayer University of Osijek, Faculty of Economics in Osijek. Osijek 2012.
[21] Finne, S., Sivonen H.: *The Retail Value Chain: How to gain Competitive advantage through Efficient Consumer Response*, Kogan Page Limited. London–Philadelphia 2009.
[22] Welbrock, W., Traumann Ch.: *Zukünftige Herausforderungen im Bereich des Handels*, Hrsg. Göpfert, I., Philipps-Universität, Marburg: 2012, https://www.uni-marburg. de/fb02/ bwl04/ publikationen/dp3.pdf, 2015-04-12.
[23] Bormann, S., Siegel G.: *Konzentrationsprozeß im Einzelhandel*, Die Linke im Bundestag, Berlin 2007, www.sabine- zimmermann.info, 2011-06-22.

[24] Segetlija, Z.: *Nove tehnologije i razvoj maloprodajnih oblika* [New Technologies and the Development of Retail Trade Forms], Proceedings of 10th International Scientific Conference Business Logistics in Modern Management, Z. Segetlija, M. Karić (Eds.), Osijek, 2010, 125–145.

[25] Magnus, K.H.: *Erfolgreiche Supply Chain Kooperation zwischen Einzelhandel und Konsumgüterherstellern,* Deutscher Universitätsverlag, Gabler Edition Wissenschaft, Wiesbaden, 2007.

[26] *Online Retailing: Britain, Europe, US and Canada 2016*, Centre for Retail Research, Newark (UK), http://www.retailresearch.org/onlineretailing.php, 2016-04-28.

[27] Happel, S.: *Die Gefahr ist der Onlineshop im Nachbarland*, Wirtscahftswoche, 15. Mai, 2015, http://www.wiwo.de/unternehmen/handel/onlinehandel-in-europa-die-gefahr-ist-der-onlineshop-im-nachbarland/11775594.html, 2016-04-28.

[28] Celko, M., Janszky S.: *Die Zukunft des stationären Handels*, Trendstudie des 2b AHEAD ThinkTanks. Leipzig 2014, http://www.2bahead.com/trendstudien/zukunft_des_stationaeren_handels, 2016-04-15.

[29] Annual detailed enterprise statistics for trade (NACE Rev. 2 G), Eurostat, 2016, http://www.eurostat.eu, 2016-04-28.

[30] Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95), Eurostat, 2016, http://www.eurostat.eu, 2016-04-28.

LOCATING A BIOREFINERY UNDER ENVIRONMENTAL CRITERIA: A GREEN FACILITY LOCATION PROBLEM

Adrian SERRANO-HERNANDEZ[1], Javier FAULIN[1], Mercedes SANCHEZ[2], Javier BELLOSO[3], Bartosz SAWIK[4]

[1]Department of Statistics and Operations Research, Institute of Smart Cities,
Public University of Navarre. Pamplona,
Spain
[2]Department of Business Management, Public University of Navarre, Pamplona,
Spain
[3]Department of Mathematical Engineering and Computing,
Public University of Navarre, Pamplona,
Spain
[4]Faculty of Management, Department of Applied Computer Science,
AGH University of Science and Technology, Krakow,
Poland

Abstract:

Underestimating facility location decisions may penalize its performance over time. Those penalties usually have been studied from the economic point of view analyzing its impact on profitability. At the same time, the concern about the obtaining of sustainability is gaining importance leading to seek for renewable energy sources to reduce greenhouse gas emissions. However, little attention has been paid on choosing a location considering environmental criteria. Thus, this work aims at determining a biorefinery location considering its impacts on natural resources. Thus, a mixed integer linear programming model is developed taking into account the crop location and the biomass production seasonality to obtain an apposite location that minimizes environmental impact.

Keywords:

Biorefinery, Logistics, Supply Chain Management, Facility Location Problem, MILP

1. INTRODUCTION

Biorefineries evolve rapidly due to the fact of a quick answer to reduce the dependence of national economies from oil materials and their derivatives. This situation is trying to be solved by developing new energy alternatives from renewable resources. Within the group of renewable energies, the biomass, being the feedstock of a biorefinery, is an important option to replace the use of fossil fuels, especially in the transportation sector. This substitution can be done because biorefineries transform biomass into liquid fuel in internal combustion engines [1] and electricity for electric vehicles [2]. Most biorefineries have focused their interest and goals on bioethanol or biodiesel production contributing to such energy goal [3]. However, biofuels are produced in large quantities but are sold at low prices making its profitability strongly dependent on market conditions, which are very difficult to control (oil and biomass prices) what leads to high volatility business. The biorefinery concept has evolved into new scenarios where biofuel production is complemented with other high-value chemical commodities in order to remedy that situation. Once it has been collected, biomass is converted into energy (for instance electricity and heat) and chemical commodities through biological and/or thermochemical processes that take place in the facility called the biorefinery [4].

Biorefinery location is a critical factor since many tactical and operational decisions (e.g. crops selection, purchase policies or stock policies) will depend on it [5]. The process of locating an industrial plant requires the analysis of several factors from many points of views: economic, social, technological, market, environmental, etc. The facility location, plant and supply chain design, and equipment selection, among others, are considered strategic decisions that involve a large amount of resources for a very long time. Actually, for many firms, the location decisions only occur once in their life. If such a strategic decision is not properly carried out, it could cause several problems that may lead to the business shutdown. For that reason, the scientific literature has tried giving a response to many questions related to the best place to locate a facility. Answers lie in the resolution of the Facility Location Problem (FLP). Nevertheless, several variants arise from the FLP. For instance, Montoya et al. [6] dealt with a multi-product FLP running a computational experiment over 288 instances with an average optimality gap of around 3%. Stochasticity approximation to location problems is described by Serrano-Hernandez et al [7] and Bieniek [8] where the randomness concept surges on production and demand problems in biorefinery analysis, respectively. Ortiz-Astorquiza et al. [9] did a theoretical study on the multi-level FLP, which mainly consists of finding the best set of facilities to open for each level in order to maximize the total profit satisfying the demand of every customer. Another FLP variant is the Location Routing Problem in which a FLP and a Vehicle Routing Problem are considered at the same time [10]. Even though there is a rich multi objective FLP literature [11,12,13,14] that takes into account environmental constraints, there are no reference to a Green FLP, that is the FLP that explicitly only takes into account environmental damage derived from the location decision. FLP applications are unlimited, and there are some typical examples of them. Such is the case of the health care problems, in which health care centers (typically hospitals [15]) should be located in order to maximize the assistance or coverage level. For instance, Belien et al. [16] optimally placed some organ transplant centers. Even though exact solutions through Mixed Integer Linear Programming problems can be easily found in the literature [17], heuristics algorithms have been developed for the FLP and many of its variants. That is the case of Lee and Lee [18] with a tabu search heuristic to solve a generalized hierarchical covering FLP. Similarly, Aytug and Saydam [19] and Shavandi and Mahlooji [20] solved the same problem with a genetic algorithm. Other examples are the next ones: Bermand et al. [21] who developed a greedy algorithm for a generalized maximal covering location problem; and Zanjirani et al. [22] with a hybrid artificial bee colony algorithm. A remarkable work is described in the Memisoglu et al.'s [23] paper in which a bioenergy supply chain is designed. They explicitly take into account the location, production, inventory, and distribution problems to configure the conjoint decisions of a biorefinery supply. Finally, the contribution of this article is twofold: on one hand, we will provide a compressive overview of a new FLP variant, the Green FLP. On the other hand, we solve it in the case of locating a biorefinery and run a sensitivity analysis once the green location has been chosen to derive optimal decisions that can be made with regard to tactical and operational decisions (e.g. crops selection, purchase policies or stock policies).

2. PROBLEM DEFINITION

In the same way that green logistics extends the traditional definition of logistic by explicitly taking into account other non-traditional external costs within all aspects of logistics; the Green FLP cares about environmental issues such as air pollution. Air pollution is caused by emission of air pollutants like particulate matter (PM), NOx and non-methane volatile organic compounds that affect people, vegetation, materials and global climate. Climate change or global warming impacts of road transport are, mainly, generated by emissions of greenhouse gases (GHG): carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Nevertheless, CO_2 is the dominant anthropogenic GHG, and the remaining GHG can be expressed as CO_2 equivalent (CO_{2e}) [24]. As previously said, the facility location problem is a strategic decision problem that will affect tactical and operational decisions when the facility is already running. For example, economically speaking, a facility should be placed in a city center, raising the area congestion which is used by the noisy and pollutant delivery trucks. People who will suffer from such nuisances due to the pure economic decision would *pay* for those external costs. For that reason, the Green FLP should take into account the whole environmental performance due to the location decision. That is, sustainability facility itself is out of the scope of this article since it is not related to location decisions. Air pollution occurs when the fuel is burnt, therefore, everything that affect fuel consumption will affect emissions as well. Distance is the major fuel consumption determinant, however, there are many other factors that can be divided into four groups [25]: (i) Vehicle related, which include the curb weight or the type of fuel it uses. (ii) Environment related, such as the road gradient, the pavement type and even the temperature and altitude. (iii) Travel related, that would include the speed and acceleration or deceleration. Finally, (iv) Driver related such as driver aggressiveness and gear selection. From those factors, speed and load are the most important ones, being the reason why applying an average emission value per kilometer is not accurate. Later, road gradient plays an important role in fuel consumption, keeping in mind that downhill does not compensate up-hill. The remaining factors still affect marginally energy consumption.

The problem addressed in this article is stated as follows. In a 10,000 km^2 study area embracing the whole Autonomous Community of Navarre in Spain, we are given a set of crops that currently produce oats, barley, corn, rape, rice, wheat, and alfalfa (those are the products where the biomass comes from); being, all of them suitable for a lignocellulosic biorefinery. Those productions came from genuine data available in the area of study. Location and major properties of each type of feedstock (e.g. humidity rate, losses in transportation, harvest times, depreciation in storage, etc.) are known. Since all the current biomass production cannot be collected for a biorefinery [26], for each product and crop an availability factor is given. Moreover, the biorefinery should be signed long term supply contracts with providers in order to guarantee a continuous flow of biomass. Storage is allowed in origin and destination, that is, once collected, the biomass can wait in either production location or biorefinery warehouse with a known time-dependent depreciation rate. With regard to the location candidates, we use all the industrial parks in the study area that were able to host such a facility. Biorefinery capacity is determined from the supply side, accounting for 150,000 tons of dried biomass during the whole year, i.e. biorefinery processes monthly 12,500 tons of biomass. Finally, having the purpose of making comparisons, genuine data about biomass prices (of each product), transportation costs and storage cost are known.

A Mixed Integer Linear Programming (MILP) model is developed to determine the best location to place the aforementioned biorefinery and to determine the tactical and operational decisions (e.g. crops selection, purchase policies or stock policies) minimizing the environmental impact. Here, the environmental impact can be measured as the distance between the crops and the chosen biorefinery location. Due to the supply chain configuration, routing is not possible since vehicles leave the biorefinery empty and return full once a crop is collected. For the same reason, payload consideration in the model can be dropped out. Vehicle related factors are not taken into account because their capacities are not considered in this model: there is only one type of truck with unlimited units. Finally, the study area has no significant road gradient differences. Being I the set of crops, J the set of potential locations, T the set of months, P the set of products, and $Y_{j,i,t}$ the binary decision variable which take 1 if at month $t \in T$, the crop $i \in I$ is selected to serve the biorefinery placed in the potential location $j \in J$ the Green FLP objective function is as follows:

$$\min \text{EnvironmentalImpact} = \sum_{j}\sum_{i}\sum_{t} Y_{j,i,t} \cdot \text{distance}_{i,j} \tag{1}$$

Remaining strategical (location) and tactical and operational decision variables are depicted in the following lines. Firstly, a binary variable X_j that takes 1, if the biorefinery is located in the potential location $j \in J$. Secondly, $Q_{p,i,t,j}$ that are the tons of product $p \in P$ bought in crop $i \in I$ at month $t \in T$ to serve potential location $j \in J$. Note that product $p \in P$ is referred to the different products (oats, barley, corn, rape, rice, wheat, and alfalfa) that may be available in each crop $i \in I$. Finally, $BioS_{p,t,j}$ that are the tons of product $p \in P$ storaged at month $t \in T$ in the potential location $j \in J$.

Where
h_p = humidity rate
$consumption_j$ = biorefinery monthly consumption
γ = depreciation rate during storage
δ = depreciation rate during transportation

The problem constraints would be the next ones:

$$\sum_{j} X_j = 1 \tag{2}$$

$$\sum_{i} Q_{p,i,t,j} \cdot (1-\gamma) + BioS_{p,t-1,j} \cdot (1-\delta) = \frac{\text{consumption}_{p,j,t}}{1\text{-}h_p} + BioS_{p,t,j}; \forall p, \forall j, \forall t \tag{3}$$

$$\sum_{p} \text{consumption}_{p,j,t} = 12500 \cdot X_j; \forall j, \forall t \tag{4}$$

$$Q_{p,i,t,j} \leq AvaiBio_{p,i,t} \cdot Y_{j,i,t}; \forall i, \forall p, \forall j, \forall t \tag{5}$$

$$Y_{j,i,t} \leq X_j; \forall i, \forall p, \forall j, \forall t \tag{6}$$

$$Y_{j,i,t} \in \{0,1\} \tag{7}$$

$$X_j \in \{0,1\} \tag{8}$$

The constraint (2) determines that a single biorefinery can be placed. Restriction (3) describes storage flows taking into account product humidity and potential losses due to both transportation and storage. Constraint (4) stablishes biomass that can be bought. Restriction (5) determines biorefinery capacity. Finally, $AvaiBio_{p,i,t}$ in constraint (4) is the total biomass available of product $p \in P$ in crop $i \in I$ at month $t \in T$. Note that it depends on product seasonality and on the availability factor $\alpha_{p,i}$ to ensure that biorefinery is not going to take a huge portion of the total production ($production_{p,i}$) [26].

$$AvaiBio_{p,i,t} = production_{p,i} \cdot \alpha_{p,i} \cdot \frac{onseason_{p,t}}{seasondur_p} \tag{9}$$

Where $onesason_{p,t}$ is equal to 1 in case product $p \in P$ is available in month $t \in T$ and $seasondur_p$ is the duration in months in which product $p \in P$ is available. Remaining constraints ensure whether a biorefinery is not built, no crop can be assigned to it (6) and force the variables $Y_{j,i,t}$ (7) and X_j (8) to be binary variables.

3. RESULTS

The MILP model was coded in GAMS software using a commercial solver to solve it running on a personal computer Intel ® Core ™ i5-2430M CPU @ 2.40 GHz, and 4 GB RAM. In order to get a better understanding of the results, Figure 1 shows the sensitivity analysis of the environmental impact versus a cost minimization objective once the facility is already running. In a first step, the Green FLP is solved giving us the best location among the tactical and operational policies (crops selection, purchase policies and stock policies) as well as its total costs. That is the point A in the Figure 1. In a second step, the location is fixed and the sensitivity analysis is applied by relaxing the environmental impact; actually, point B corresponds to the solution to the traditional cost minimization problem. Note that in the economic valuation real biomass prices, transportation and storage costs have to be taken into account. However, the reader should take in mind that the Green FLP is solved once to determine the location. Later, a traditional cost optimization model can be run but the location is already solved.

As can be seen in Figure 1, differences in terms of environmental impact and cost can be significant, being the decision maker able to choose among all the efficient line that corresponds to different tactical and operational configurations: crops selection, purchase policies and stock policies. Actually, the greener the supply chain is, the higher is its cost. Finally, note that there is a point C in which may not be worthy to keep greening the supply chain beyond that point, because, higher environmental impact reduction would involve great increases in cost. By doing so, minimum cost is not achieved (it would be point B) nonetheless a huge environmental impact is reached (75% reduction) by slightly increasing costs (around 1%).

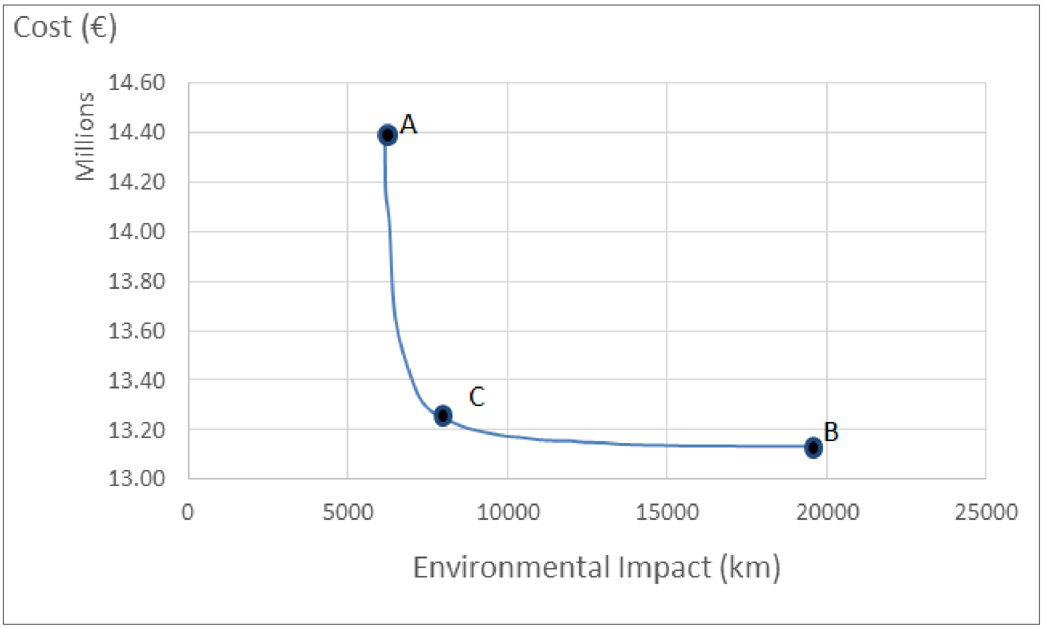


Figure 1 – Sensitivity Analysis Cost vs Environmental Impact

4. CONCLUSIONS AND MANAGERIAL INSIGHTS

Facility location decisions are strategic having influence in forthcoming tactical and operational results. The underestimation of the importance of facility location decisions would lead them to being vulnerable to several threats that may jeopardize its survival. Facility Location Problem faces that situation in such a way potential locations are evaluated in order to choose a suitable place that may have to do with coverage objective (such as locating a hospital) o classical cost minimization. However, a Green Facility Location Problem is introduced in this paper with the aim of choosing the location that minimizes overall environmental impact, that is taking into account tactical and operational decisions. A case study is carried out in which a biorefinery should be located minimizing its environmental impact. Biorefinery management would take advance of sensitivity analysis in order to identify its key processes that allow them to empower their performance at both economic and environmental level. Management can adjust tactical and operational characteristic to choose the point they prefer in the sensitivity analysis (Figure 1), once the Green FLP have selected the location.

5. ACKNOWLEDGEMENTS

This work has been partially supported by the Spanish Ministry of Economy and Competitiveness (TRA2013-48180-C3-P and TRA2015-71883-REDT), and the Ibero-American Program for Science and Technology for Development (CYTED2014-515RT0489). Likewise, we want to acknowledge the support received by CAN Foundation in Navarre, Spain (Grant CAN2015-70473) and NCN Grant (DEC-2013/11/B/ST8/04458).

6. REFERENCES

[1] Börjesson, M., Ahlgren E., Lundmark R., Athanassiadis D.: *Biofuel futures in road transport– A modeling analysis for Sweden* Transportation Research Part D: Transport and Environment, 32 (2014) 239–252.

[2] Juan, A., Mendez C., Faulin J., de Armas J., Grasman S.: *Electric Vehicles in Logistics and Transportation: A Survey on Emerging Environmental, Strategic, and Operational Challenges*, Energies, 9(2)(2016), 1–21.

[3] Papendiek, F., Tartiu V., Morone P., Venus J., Hönig A.: *Assessing the economic profitability of fodder legume production for Green Biorefineries–A cost-benefit analysis to evaluate farmers profitability*, Journal of Cleaner Production, 112(2016), 3643–3656.

[4] Cherubini, F., Jungmeier G., Wellisch M., Willke C., Skiadas I., Ree R., Jong E.: *Toward a common classification approach for biorefinery systems,* Biofuels, Bioproducts and Biorefining 3(5)(2009), 534–546.

[5] Daskin, M.: *Network and Discrete Location: Models, Algorithms, and Applications*, John Wiley and Sons, Inc., New York, 2013.

[6] Montoya, A., Vélez-Gallego M., Villegas J.: *Multi-product capacitated facility location problem with general production and building costs*, NETNOMICS: Economic Research and Electronic Networking, 1(2016), 1–24

[7] Serrano-Hernandez, A., Faulin J., Astiz P., Sánchez M., Belloso J.: *Locating and Designing a Biorefinery Supply Chain under Uncertainty in Navarre: A Stochastic Facility Location Problem Case*, Transportation Research Procedia, 10(2015), 704–713

[8] Bieniek, M.: A note on the facility location problem with stochastic demands, Omega 55(2015), 53–60.

[9] Ortiz-Astorquiza, C., Contreras I., Laporte G.: *Multi-level facility location as the maximization of a submodular set function*. European Journal of Operational Research 247(2015), 1013–1016.

[10] Koç, Ç., Bektaş T., Jabali O., Laporte G.: *The impact of depot location, fleet composition and routing on emissions in city logistics*, Transportation Research Part B: Methodological, 84(2016), 81–102.

[11] Liu, Z., Qiu T., Chen B.: *A study of the LCA based biofuel supply chain multi-objective optimization model with multi-conversion paths in China*, Applied Energy, 126(2014), 221–234.

[12] Bashiri, M., Rezanezhad M.: *A reliable multi-objective p-hub covering location problem considering of hubs capabilities*. International Journal of Engineering, Transactions B: Applications, 28(5)(2015), 717–729.

[13] Zhao, J., Verter V.: *A bi-objective model for the used oil location-routing problem*, Computers and Operations Research, 62(2015), 157–168.

[14] Gutjahr, W., Dzubur N.: *Bi-objective bilevel optimization of distribution center locations considering user equilibria*, Transportation Research Part E: Logistics and Transportation Review, 85(2016), 1–22.

[15] Chatterjee, D., Mukherjee B.: *Potential Hospital Location Selection using AHP: A Study in Rural India*, International Journal of Computer Applications, 71(17)(2013), 1–17.

[16] Beliën, J., De Boeck L., Colpaert J., Devesse S., Bossche F.: *Optimizing the facility location design of organ transplant centers*, Decision Support Systems, 54(4)(2013), 1568–1579.

[17] Tragantalerngsak, S., Holt J., Rönnqvist M.: *An exact method for the two-echelon, single-source, capacitated facility location problem*, European Journal of Operational Research, 123(3)(2000), 473–489.

[18] Lee, J., Lee Y.: Tabu based heuristics for the generalized hierarchical covering location problem, Computers and Industrial Engineering, 58(4)(2010), 638–645.

[19] Aytug, H., Saydam C.: *Solving large-scale maximum expected covering location problems by genetic algorithms*: A comparative study, European Journal of Operational Research, 141(3)(2012, 480–494

[20] Shavandi, H., Mahlooji H.: *A fuzzy queuing model with a genetic algorithm for congested systems*, Applied Mathematics and Computation, 181(1)(2006) 440–456.

[21] Berman, O., Krass D., Menezes M.: Facility reliability issues in network p-median problems: Strategic centralization and co-location effects, Operations Research, 55(2)(2007), 332–350.

[22] Zanjirani, R., Hassani A., Mostafa S., Bakhshayeshi M.: *A hybrid artificial bee colony for disruption in a hierarchical maximal covering location problem*, Computers and Industrial Engineering, 75(2014), 129–141.

[23] Memişoğlu, G., Üster H.: *Integrated Bioenergy Supply Chain Network Planning Problem*, Transportation Science, 50(2015), 35–36.

[24] Lera-López, F., Faulin J., Sánchez M., Serrano-Hernandez A.: Evaluating factors of the willingness to pay to mitigate the environmental effects of freight transportation crossing the Pyrenees, Transportation Research Procedia, 3(2014), 423–432.

[25] Demir, E., Bektas T., Laporte G.: *A review of recent research on green road freight transportation*, European Journal of Operational Research 237(2014), 775–793.

[26] Luo, L., Voet E., Huppes G.: *Biorefining of lignocellulosic feedstock – Technical, economic and environmental considerations*, Bioresource Technology, 101(13)(2010), 5023–5032.

PRACTICES OF CORPORATE SOCIAL RESPONSILITITY IN LARGE BRAZILIAN INDUSTRIAL COMPANIES: AN EMPIRICAL STUDY

Maria C.F. de SINAY[1], Gabriel A. de ARAUJO[2], Laura SINAY[3], Marta C. DALBEM[4]

[1,2]University of Grande Rio, Rua da Lapa 90, Rio de Janeiro, Brazil
[3]Federal University of the State of Rio de Janeiro, Av. Pasteur 458 – IBIO, Rio de Janeiro, Brazil
[4]Independent Consultant, Ipanema, Rio de Janeiro, Brazil

Abstract:

Corporate social responsibility (CSR) is a relevant topic for societies, businesses and science, due to the awareness of society about the scarcity of natural resources, to the wide consequences of environmental accidents and to the raise of consciousness about stakeholders' issues. The purpose of this paper is to assess the corporate social responsibility as practiced by large Brazilian industrial companies. To achieve this, secondary data collected from a technical Brazilian magazine, were used, to represent the behavior of large industrial firms related to the level of adoption of 12 CSR practices. From the results, it can be observed that some of the practices where implemented by more than 80% of the industries while others were implemented by less than 50% of then. Trends were also analyzed.

Keywords:

Corporate Social Responsibility in Brazilian Industries; Industrial Corporate Responsibility and Sustainability; Corporate Social Responsibilities' Activities

1. INTRODUCTION

Corporate Social Responsibility, as defined by the World Business Council for Sustainable Development (WBCSD), can be understood as a permanent commitment of business' leaders to adopt an ethical behavior and to contribute to economic development, improving, simultaneously, the quality of life of employees and their families, of the local community and of society [1].

The European Commission Policy in 2011 defined CSR as the organizations' responsibility for their impacts on society, recommending the implementation of actions as: disclosure and dissemination of best practices; improvement of self-regulation; consumption and investment's policies aligned with responsible business conducts; sponsor research and training in CSR; and transparency regarding business management relations with social and environmental areas [2].

These recommendations were aligned with the basic principles established by the international ISO 26000 guideline [3] for CSR, namely: responsibility, transparency, ethical behavior, respect and recognition to stakeholders, to constitutional rights, to international norms and to human rights.

In Brazil, the NBR 16001 norm, issued by the Brazilian Association for Technical Norms (ABNT) defines social responsibility as the "ethical and transparent relationship the organizations have with all stakeholders, for the purpose of a sustainable development" [4].

External variables, such as the markets dynamism/ turbulence, technological developments, as well as the organizations' internal variables - strategy, values and philosophy of the upper tiers, culture, organizational structure, use of productive capacity and choice of resources – , contributed to change the corporations attitude in the middle of the 1950's [5].

Private organizations started realizing that actions focused exclusively on maximizing shareholders' profits yield insufficient results, being, therefore, necessary to take new action towards sustainable development, so that employees, community and clients would be also, directly or indirectly, benefitted from them. While doing this, organizations would keep their positions in the markets [6].

The entry of multinational companies in Brazil in the 1940s/1950s and the access to information via radio and television in the following decade promoted significant changes in customs and work relations, but the dictatorial political regime at that time discouraged explicit popular discussions and eventually hampered the spread of CSR. It was only in the 1980s, upon political freedom and mostly due to the widespread internet communications worldwide, that social movements were able to work for the rights and responsibilities of the consumer.

Research conducted by Quorum Brazil Institute and published in *Exame* magazine in 2008 showed that 74% of the respondents, all Brazilians, were concerned with environmental issues, while 59% reported their purchasing decisions to be dependent upon the product being ecologically friendly [7]. These are the conscious consumers, who balance consumption with the planet sustainability, according to Hillman and Keim [8].

KPMG in 2011 reported that 95% of the 250 largest worldwide companies disclosed public social reports, detailing their CSR activities. In Brazil, this stake was 88% [9].

This theme is extensive and does not bear clear boundaries; hence there are varied concepts and theories on CSR, which has yielded controversial research results, including whether CSR improves or not organizations' performance: although there are already numerous studies attempting to compare organizations' social and environmental actions with their financial performance, results do not converge.

Authors such as Freedman and Jaggi [10], Klassen and McLaughlin [11] and Russo and Fouts [12] have been trying to demonstrate, since the 1980s, the existence of a positive correlation among an environmentally friendly management and the company's operating performance. These researchers achieved results with no satisfactory statistically significance, which lead to the need of further research on this theme.

Other authors have focused their work on investigating if CSR companies reap recognition from employees. Sen, Bhattacharya and Korschun [13] and Wright and Nyberg [14] found a positive correlation among these two variables, while Fineman [15] found a weak correlation and emphasized that companies should establish clear objectives and communication channels in order to strengthen the recognition of the company's concern with CSR.

In the research field, controversy results from a number of different CSR theories. Garrida and Melé [16], from the Spanish *Universidad de Navarra*, mapped four theoretical frameworks, depending on the objectives or on the type of interaction company society: (1) Instrumental theory – considers CSR actions as those that generate shareholders financial profits [17,18]; (2) integrative or stakeholders oriented theory - considers that companies attempt to meet social demands because they recognize that their businesses depend upon society to exist, grow and perpetuate, therefore, they focus on stakeholders, rather than exclusively on shareholders [19]; (3) ethical theory - considers that ethical objectives should prevail in organizations, resulting in respect for stakeholders' interests, social rules, fair play and human rights, all these leading to sustainable development [20]; and (4) political theory - associates the power and responsibilities of organizations to the political arena, recognizing their capacity to influence sectors and markets [21]. Garrida and Melé conclude that a fifth framework is being developed, integrating the above mentioned four, in order to reduce controversy in CSR research [16].

The objective of this descriptive and quantitative study is to verify how the largest Brazilian industries practice Corporate Social Responsibility. The analysis is based on secondary data disclosed by the annual reports of a Brazilian periodical, *Gestão Ambiental*, published by Editora Análise, which surveys over 500 Brazilian companies every year [22]. According to Matten and Moon, (2008), CSR practices are a reflex of the embedded social, institutional, cultural, national, geographical and historical contexts, therefore CSR actions must be chosen taking into account the company's and its region's peculiarities, making this analysis of Brazilian industries' actions towards CSR relevant.

Several of the CSR practices yield financial return to the companies themselves, either in the form of brand marketing (strategic philanthropy), or by collecting and reusing components of goods discharged by users (reverse logistics), by having a better trained workforce and, specially, by the innovation and creativity that blossoms from the pursuit of better and more environmentally friendly raw materials and processes. Therefore, CSR has become a priority for contemporary organizations, no longer viewed as a source of new costs and constraints, but rather a source of new opportunities and innovation.

2. METHODOLOGY

This empirical research analyses how large Brazilian industries perform in terms of the CSR practices identified in the literature. This analysis is based on data disclosed by the periodical *Gestão Ambiental* annual reports, published by *Editora Análise*, for the 20082013 period. *Editora Análise* is the first Brazilian journalistic company focused exclusively on specialized themes and currently runs eight periodicals on different research themes, all based on primary data. *Gestão Ambiental* was launched in 2007, has a circulation of around 30,000 units and runs annual reports based on primary data collected by their analysts through an on-line survey at the 500700 largest Brazilian companies. This research measures the evolution of a sample of Brazilian industries along 20082013, regarding 12 CSR practices aligned with the literature review and detailed in Table 1. These practices are also aligned with an integrated view of CSR as proposed by Garrida and Melé [16], except for the actions to influence the political arena, which are not directly contemplated in the online survey filled in by the sampled of industries studied.

Table 1 – CSR Practices

CSR Practice	Definition
1. Strategy alignment with CSR	Identifies if the company takes social and environmental issues into account when formulating its strategy, so that these issues are relevant in practice and in all organizational levels, not just an addendum to an already existing strategy.
2. Educational environmental programs	Identifies if the company provides training on environmental issues to stakeholders, for example, employees and local community.
3. Environmental Projects for the community	Environmental activities, other than environmental education, directed to those who are not directly related to the company.
4. Disclosure of CSR practices to the community	Identifies if the company informs its social and environmental activities to stakeholders, with focus on transparency.
5. Use of renewable energy sources	Identifies if the company uses renewable energy sources, such as biomass, solar, biofuels, wind, hydrogen, others.
6. Actions to make employees aware of conscious consumption practices, especially regarding basic resources	Identifies if the company makes campaigns to turn employees more conscious consumers of water and energy.
7. Efficient use of basic resources	Identifies if the company runs structured programs for the adequate consumption of basic resources.
8. Internal social and environmental audits	Detects if the company adopts internal audits as a way of fostering social and environmental practices.
9. Incentives to eco-efficient activities	Indicates if the company adopts practices such as reuse, recycling, reduction of effluents and solid waste.
10. Monitoring of pollution levels	Checks if the company controls solid and liquid emissions systematically.
11. Adoption of end of pipe technologies	Checks if the company has effluents treatment facilities and adopts processes to reduce the environmental impact of solid waste.
12. Accountability for the environmental hazards caused by the company	Refers to the environmental liabilities reported in the company's statements and reports.

3. RESULTS

The data base refers to the 20082013 period and reports respectively how 374, 368, 283, 288, 250, and 270 sampled Brazilian industries performed regarding the twelve CSR practices listed in Table 1. The industries in the sample had net revenues over R$ 60 million/year (enough to be classified as large companies, according to Brazil's Institute of Geography and Statistics – IBGE criteria)

Results are presented in Table 2, showing the percentage of industries, per year, that comply with each of the twelve CSR practices.

In four of the CSR practices, adherence exceeded 80%: on average, 96.0% of industries engage in educational environmental programs (practice 2); 90.9% perform internal social and environmental audits (practice 8); 87.5% monitor pollution levels (practice 10) and 84.6% disclose their CSR practices to the community (practice 4). In the industrial sector, only practice 12, accountability for the environmental hazards caused by the company, shows less than 30% adherence.

Table 2 – Industry's adherences to CSR practices in the period 2008–2013 (source: based on data disclosed by *Gestão Ambiental*).

CSR #	**CSR Practice**	2008	2009	2010	2011	2012	2013	Average
1	Strategy alignment with CSR	65,5	64,1	66,2	67,0	73,1	70,2	67,7
2	Educational enviromental programs	94,1	94,3	95,4	95,8	98,1	98,2	96,0
3	Environmental projects for the communities	62,3	62,2	69,7	69,1	76,5	69,0	68,1
4	Disclosure of CSR practices to the community	81,3	82,9	84,2	85,1	86,4	87,5	84,6
5	Use of renewable energy sources	38,8	42,7	43,7	44,1	55,9	50,5	46,0
6	Actions to make employees aware of conscious consumption	70,3	76,6	78,9	77,8	81,7	77,7	77,2
7	Efficient use of basic resources	44,1	47,0	48,8	47,6	58,5	50,9	49,5
8	Internal social and environmental audits	90,7	89,2	87,4	91,5	92,6	93,9	90,9
9	Incentives to eco-efficient activities	56,7	59,5	58,3	59,4	65,8	63,5	60,5
10	Monitoring of pollution	85,1	86,6	85,8	87,2	90,6	89,7	87,5
11	adopting of end-of-pipe technologies	76,4	72,1	76,3	78,3	83	81,9	78,0
12	Accountability for the environmental hazards caused by the company	30,2	27,7	26,1	26,4	28,4	26,4	27,5

In eleven of the twelve practices, the percentage of adherent companies has grown along the chosen 6 year time frame, but only practice 5 – use of renewable energy sources reached over 10% of additional adherence. Therefore, there is a slighter trend of improvement, perhaps explained by the already higher adherence to CSR practices, overall. Practice 12 – accountability for the environmental hazards caused by the company – , however, not only shows a meager adherence, but also a downward trend, as compared to 2008 results, with less 3.8% adherents in 2013.

Table 3 summarizes results, detailing both the average adherence to CSR practices in the 6 year period and the overall trend observed in the 20082013 period.

Table 3 – Summary for Industry Sector, overall adherence in the 2008–2013 period

Sector	Overall Average Adherence%	Trend	Highest Adherence	Lowest Adherence
Industry	69.5	Mild Growth	Practice 2 (96.0%)	Practice 12 (27.5%)

Figures 1, 2 and 3 present the annual average adherences to all 12 practices per year, dividing this in strong adherence (practices 2, 4, 8 and 10), mild adherence (practices 1, 3, 6 and 11) and low adherence (practices 5, 7, 9 and 12).

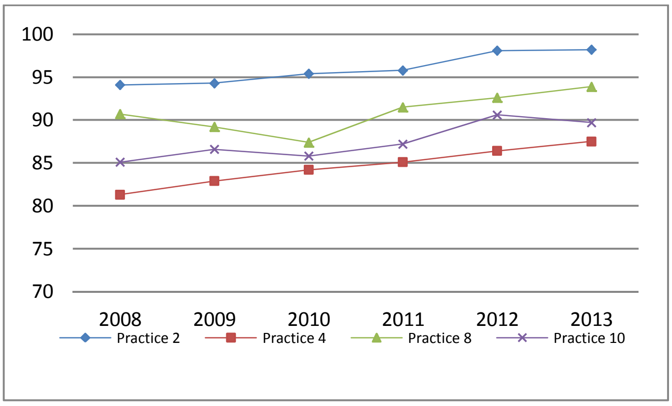


Figure 1 – Strong Adherences (source: based on data disclosed by *Gestão Ambiental*)

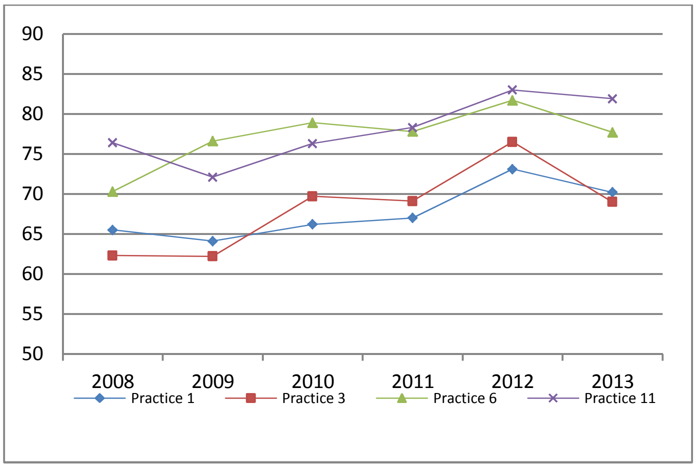


Figure 2 – Mild Adherences (source: based on data disclosed by *Gestão Ambiental*)

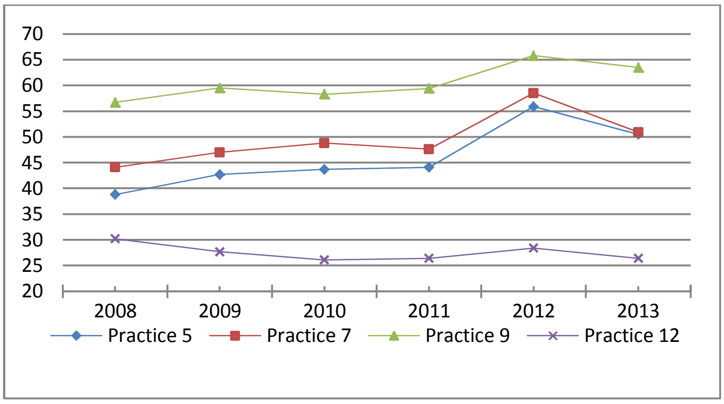


Figure 3 – Low Adherences (source: based on data disclosed by *Gestão Ambiental*)

The industrial sector, although showing significant scores of adherence, still has plenty room for improvements since it has been presenting only a mild growth, never above 10% in each year.

Educational environmental programs (practice 2) has enjoyed the highest adherence in this sector, signaling the companies concern in clarifying employees, suppliers and partners about the importance of sustainable practices. This is one of the cheapest actions to adopt and maintain, and also the first one to be implemented, what might explain this outstanding performance.

On the other hand, practice 12 – accountability for the environmental hazards caused by the company – has the lowest score of adherence even when industries should pay particular attention to the fact they have relevant impact on the environment and, therefore, they should be more threatened by the bad image presented and by legal risks.

4. CONCLUSIONS

Results show that the industrial sector, which have a more hazardous impact in Brazil, in general adhere significantly to CSR practices. Industrial companies also seem to be pursuing an integrated view of CSR, scoring well in a high number of CSR practices, perhaps because they have been the more frequent targets of activist consumers, government scrutinizing and society's claims. Nevertheless, this sector still shows low adherence to eco-efficient and/or accountability practices, for example, signaling that industries are still far from meeting the standards prescribed by a CSR integrated theory.

Downturns in some CSR practices have been observed more recently, especially regarding the use of renewable energy, which dropped in all economic sectors in 2013. This is another signal that CSR is still seen as discretionary by a number of companies, which tend to neglect environmentally friendly practices during economic downturns. Educational programs on sustainability (practice 2) and disclosure of the companies' CSR actions (practice 4) showed the highest adherence in this sector. We deem it as a signal that companies adhere easily to low-cost actions that also yield branding and image benefits, an attitude that is clearly aligned with instrumental objectives, only.

The lowest adherence ratios refer to reporting environmental hazards/liabilities (practice 12) and programs towards the efficient use of basic resources (practice 7), a signal that companies still act as free-riders when it comes to their impact on natural resources, failing again to comply with the ethical, stakeholders oriented and political CSR guidelines.

As a general conclusion, our research indicates some paths for improvement: Brazilian industrial sector needs to make more use of renewable energy sources, implement more environmental projects in their communities and be more transparent regarding the hazardous impacts of their activities.

This research has limitations inherent to self-selection sampling and from self-evaluation. Nevertheless, the large number of responses is an upside that cannot be neglected. Even considering a potential optimism that might result from the constraints, it is noteworthy that this research mapped the evolution of this sector as well as paths for CSR improvements for Brazilian industries.

For future research, we suggest in-depth interviews with companies in the four economic sectors (agro industry, industry, commerce, services), addressing their difficulties and results in each of the 12 CSR practices. These case studies might also include their views on the feasibility of adopting political CSR practices in Brazil.

5. ACKNOWLEDGMENTS

The authors would like to thank CNPq (National Council of Technological and Scientific Development) and CAPES, Brazilian scientific nonprofit Agencies that partially supported this research.

6. REFERENCES

[1] Melo Neto, F., Froes C.: *Social Responsibility & Corporate Citizenship*, Qualitymark 1999.

[2] European Commission: *Summaries of EU Legislation*, Brussels 2011, http://europa.eu/legislation_summaries/, 01- 2013.

[3] International Organization for Standardization: Social Responsibility, *ISO 26000 family of international standards. ISO 2010*, http://www.iso.org/iso/home/standards/iso26000.htm, 06-2013.

[4] ABNT, N.: *Social Responsibility – Management System – Requirements*. Brazilian Association of Technical Standards (ABNT), Brazil 2004.

[5] Covin, J.G., Slevin D.P.: *A conceptual model of entrepreneurship as firm behavior*. Entrepreneurship: Critical perspectives on business and management 3(1991).

[6] Porter, M.E., van der Linde, C.*: Toward a new conception of the environment-competitiveness relationship*, The Journal of Economic Perspectives (1995), 97118.

[7] Exame. Guide to Sustainability 2008, São Paulo 2008.

[8] Hillman, A.J., Keim G.D.*: Shareholder value, stakeholder management, and social issues: what's the bottom line?* Strategic Management Journal, 22(2)(2001), 125139.

[9] KPMG: *International Survey of Corporate Responsibility Reporting*, 2011,http://www.kpmg.com/PT/pt/IssuesAndInsights/Documents/corporate-responsibility2011.pdf, 12-2013.

[10] Freedman, M., Jaggi B.: *Pollution disclosures, pollution performance and economic performance*, Omega, 10(2)(1982), 167176.

[11] Klassen, R.D., McLaughlin C.P.: *The impact of environmental management on firm performance*, Management Science, 42(8)(1996), 11991214.

[12] Russo, M.V., Fouts P.A.: *A resourcebased perspective on corporate environmental performance and profitability*, Academy of Management Journal, 40(3)(1997), 534559.

[13] Sen, S., Bhattacharya C.B., Korschun D.: *The role of corporate social responsibility in strengthening multiple stakeholder relationships: A field experiment*, Journal of the Academy of Marketing science, 34(2)(2006), 158166.

[14] Wright, C., Nyberg D.: *Working with passion: Emotionology, corporate environmentalism and climate change*, Human Relations, 65(12)(2012), 15611587.

[15] Fineman, S.: *Emotion and Organizing*. In C. Hardy, S. Clegg, W. Nord (Eds.), *Handbook of organization studies*., London: Sage1996.

[16] Garriga, E., Melé D.: *Corporate social responsibility theories: Mapping the territory*, Citation Classics from the Journal of Business Ethics 2013, Springer Netherlands 2013, 69–96, http://www.gife.org.br/, 01-2013.

[17] Friedman, M.: *The Social Responsibility of Business is to Increase its Profits*, New York Times Magazine 13 (1970).

[18] Porter, M.E., Kramer M.R.: *The competitive advantage of corporate philanthropy*. Harvard Bussiness Review (2002).

[19] Preston, L. Post J.: *Private Management and Public Policy. The Principle of Public Responsibility*, Prentice Hall, Englewood Cliff, NJ 1975.

[20] Wood, D.J: *Corporate social performance revisited*, Academy of Management Review, 16(4)(1991), 691718.

[21] Davis, K.: *Can business afford to ignore social responsibilities?*, California Management Review 2(1960), 7076.

[22] Editora Análise: *Análise Gestão Ambiental(20082013)*, São Paulo. Available in: http://www.analise.com. 05-2014.

[23] Akatu Institute; *Guide – Twelve Principles of Conscious Consumer.* São Paulo 2006. Available in: http://www.akatu.org.br/Content/Akatu/Arquivos/file/NOCAKATU

FACTORS EFFECTING POLICE STATION EFFICIENCY

Zilla SINUANY-STERN[1], Vered KUSHNIR-BERDUGO[2], Doron ALPER[1]

[1]Ben-Gurion University of the Negev, Dept. of Ind. Eng. & Mgmt.
POB 643, Beer-Sheva 84105,
Israel
[2]Israeli Police Headquarters, Jerusalem
Israel

Abstract:

The purpose of this study is to identify regional and urban factors effecting police station efficiency in Israel. At the first stage, Data Envelopment Analysis (DEA) is used to measure the efficiency of 60 police stations, based on 2 inputs and 16 outputs, including some logistic parameters. At the second stage, multiple-regression is performed to verify the effect of various regional and urban factors on the efficiency. Two factors were significant: number of vehicles belonging to the population in the jurisdiction area of the station, and the southern region.

Keywords:

efficiency; logistics; data envelopment analysis (DEA), police performance, linear programming, statistical inference

1. INTRODUCTION

This study provides an assessment of police station efficiency in Israel via Data Envelopment Analysis (DEA) – developed by Charnes, Cooper and Rhodes (CCR) [1]. DEA measures the relative efficiency of organizational Decision Making Units (DMU), a police station in this study, when multiple outputs are sharing multiple inputs, where their weights are not given. The basic DEA model uses as an efficiency measure the ratio between sum of weighted outputs and sum of weighted inputs, utilizing linear programming. For each DMU, the model finds the ideal weights of each input and output, which maximize its efficiency. The scale of the efficiency measure is between zero and 1 (or 100%).

DEA is a non-parametric approach; its advantage, in relation to the parametric approach in the police context is review by [2,3]. Over the past twenty years, DEA became an acceptable tool for measuring non-profit institution efficiency [4], and also police efficiency, in various countries such as the UK [5,6].

In this study, 2 inputs and 16 outputs were used to measure the efficiency of police stations in Israel. Various parties from police headquarters were involved in selecting the I/O variables – including some logistic parameters. Moreover, the relevant literature was reviewed to verify the choice of variables [3].

The optimal weights of the inputs and outputs, derived by DEA, vary greatly from one police station to another. Thus, bounds were put on the weights to reduce their variability, and to avoid many zero weights.

There was a claim that besides inputs and outputs there are regional and urban differences among police stations, which affect their efficiencies, such as: population size, area, and type of population. Thus, as a second stage, multiple regressions were performed, to verify the effect of various regional and urban parameters on police station efficiency.

2. DEA MODEL

The basic version of DEA model – CCR [1], assumes constant-returns-to-scale (CRS). It measures the total efficiency of n DMUs, where each has s outputs sharing m inputs. Given, X_{ij}, the past value of input i, of DMU j (for all $i = 1, ..., m$ and $j= 1, ..., n$), and, Y_{rj}, the past value of output r of DMU j (for all $r=1, ..., s$) – n problems are solved, one for each DMU. The problem of DMU k finds, v_{ik}, the optimal weight of input i, of DMU k, and u_{rk}, the optimal weight of output r of DMU k, which maximize the relative efficiency measure of DMU k, h_k. The basic ratio used here is the ratio between the sum of weighted outputs and weighted inputs.

The Linear Programming (LP) formulation of this model is:

$$\max h_k = \sum_{r=1}^{s} [u_{rk} y_{rk} + \omega_k] / \sum_{i=1}^{m} v_{ik} x_{ik} \quad (1)$$

S.T.

$$\sum_{r=1}^{s} [u_{rk} y_{rj} + \omega_k] / \sum_{i=1}^{m} v_{ik} x_{ij} < 1, \forall j = 1...n \quad (2)$$

$$u_{rk}, v_{ik} \geq \varepsilon, \forall i = 1...m, r = 1...s \quad (3)$$

The original model (CCR) assumes constant returns to scale (CRS); namely $\omega_k = 0$, and $\varepsilon = 0$. If, with its ideal weights DMU k does not receive the maximal efficiency score of 1 (100%), then DMU k is not efficient; i.e., other DMUs (or a combination of DMUs) receive the maximal score of 1, for the ideal weights of DMU k. However, if DMU k receives the maximal efficiency rate of 1, then unit k is relatively efficient. Thus, the efficient-frontier is the collection of the efficient DMUs (which receive efficiency value of 1).

Banker, Charnes and Cooper (BCC) [7] extended DEA to variable-returns-to-scale (VRS), where ω_k is not limited – it can be negative or positive. The term ω_k reflects returns to scale; it is analogous to fix costs. BCC (VRS) version of DEA was used in this study.

2.1. Weights restrictions

In the two DEA versions, CCR and BCC, the input and output weights vary greatly from one DMU to another DMU. Since the LP problem has extreme point solution, obviously, many weights will be zero, while there will be large weights for other I/O variables (for each DMU). Even a simple bound, ε, put on the weights is often zero, because it is close to zero – due to infeasibility problems; thus, resulting in unacceptable marginal rates of substitution between outputs/inputs. The solution, often suggested in the DEA literature, is to impose restrictions on the weights [8]. The variability of the units of measurement of the outputs/inputs makes it very difficult to relate to direct bounds on the weights, or on the ratios between the weights. Imposing restrictions on the ratio between the various weights, does not necessarily prevent them from being zero.

In this study, upper and lower bounds were put on the virtual variables [9]. The virtual input *i* is defined as the multiplication between the input *i* and its weight. The contribution of each virtual input to the overall composite input can be bounded percentage-wise. For example, in order to bind the contribution of input *i* to the overall weighted inputs, between 20% and 70%, the bound constraint will be:

$$0.2 \le v_{ik} x_{ik} / \sum_{\ell=1}^{m} v_{\ell k} x_{\ell k} \le 0.7 \qquad (3)$$

Such bounds can be put on each virtual output, too. These types of restrictions are used, since it is easier to extract such intuitive information from the police participants (as there is no dependence between the restrictions and the type of units of measurement of each input/output variable). This type of constraint on the virtual variables is implemented by the software Frontier Analysis (ibid), used in this study. Thus, the problem of dependence of weights on units of measurements is resolved. Obviously, with constraints, the efficiencies are less than or equal to the non-constrained version.

2.2. The two stage process

In the literature, in order to test the effect of various environmental factors on the efficiency, regression analysis was used. The dependent variable of the regression is the DEA efficiency score, while the explanatory variables are environmental factors [10]. Similarly, in our study, at the first stage DEA efficiency score is calculated. At the second stage, the DEA score was regressed against the environmental variables.

3. THE ISRAELI POLICE CASE STUDY

The organizational structure of the Israeli Police Force and its modus operandi has been shaped by social and political developments, which have occurred since the period of the British Mandate (1917–1948). Historical events brought about the development of a National Police Force that performs such functions as: maintaining order, fighting crime and serving the public, as well as taking responsibility for the internal security of the State.

There are three levels of command in a Police District: District, Region, and Police Station. The station is a sub-unit of a district or region, and is designed to function as an independent police unit that performs the basic police services within its territorial jurisdiction:

- Crime Prevention
- Crime Investigation and Discovery
- Apprehension of criminals and bringing them to trial
- Surveillance and coordination of road traffic
- Maintaining pubic order and securing life and property
- Safeguarding the security of prisoners and detainees
- Responsibility for internal security

Various planning units in Police Headquarters are responsible for overall managerial and strategic planning aspects of all police stations in Israel; among them is the Operations Research unit.

Sixty Israeli police stations were included in this study [11].

3.1. Inputs

Data chosen is affected by the availability of the data, and by the number of DMUs in the study. A rule of thumb is that the number of DMUs should be more than 3 times the number of variables (inputs and outputs). Selection of the inputs and outputs is crucial in DEA. Moreover, in police station evaluation, the differentiation between inputs and outputs can be controversial [6].

The input and output data in this study were taken from the data-base of the Police information system of 2007. These inputs represent labor and capital. Altogether, two inputs were used: 1. the number of police personnel on active duty, and, 2. the number of police cars in use at each police station. These inputs reflect the logistic structure of police stations [11].

3.2. Outputs

Most often used outputs in the literature are: number of various types of clear-ups and rates of various clear-ups. However, the number of various crimes is sometimes cited as *inputs* [5], at other times cited as *outputs* [10]. They were used here as outputs, since they reflect the volume of work of all the units of a police station (the first 7 outputs in the list below).

Altogether 16 outputs were used: the first 7 output-variables reflect volume of work performed by the police, while the last 8 output-variables reflect the successes (quality) of the police in handling the cases. These are the 16 output variables:

1) Number of files initiated by the police: drugs, weapons, bribery, gambling, and extortion
2) Total number of files with indictments
3) Total number of files with indictments concerning crimes of burglary or vehicle theft
4) Total number of files with indictments concerning crimes of aggravated violence
5) Total number of arrests with remand in custody
6) Total number of arrests with remand in custody, concerning crimes of burglary and vehicle theft
7) Total number of arrests with remand in custody concerning crimes of aggravated violence
8) Total delays of police cars to police incidents/calls*
9) Percentage of files initiated by the police
10) Percentage of files with indictments
11) Percentage of files with indictments concerning crimes of burglary and vehicle theft, from the total amount of files with indictments concerning crimes of burglary and vehicle theft
12) Percentage of files concerning crimes of aggravated violence, from the total amount of files concerning crimes of aggravated violence
13) Percentage of arrests with remand in custody, from the total amount of arrests
14) Percentage of arrests with remand in custody with indictments concerning crimes of burglary and vehicle theft, from the total amount of files with indictments concerning crimes of burglary and vehicle theft
15) Percentage arrests with remand in custody concerning crimes of aggravated violence, from the total amount of files with concerning crimes of aggravated violence
16) Percentage of traffic reports issued for offences involving pedestrians, speeding, driving through red lights, lane deviation, etc., from the total amount of traffic accidents resulting in injuries.

Outputs 8 and 16 reflect logistic elements of police performance. Output 8 is to be minimized, thus we used its reciprocal.

4. RESULTS AND ANALYSES

As outlined in section 2.2, two stage analyses were used, as follows.

4.1. Stage 1 – Calculating DEA Efficiency Scores

Table 1 presents a summary of DEA – VRS (BCC) efficiency scores of the 60 police stations, using constraints the on inputs and outputs (*u,v*) as detailed in section 2.1. Only 8 stations were efficient, while, 52 were not efficient. Note that in the non-constrained model 33 stations were efficient. The bounds on the weights of the first input (manpower) ranged between 50% and 95%. The bounds of the weights of the outputs ranged between 2% and 70% depending on the importance of each output.

Table 1 – Distribution of the efficiency of 60 police stations

Efficiency Scores	Number of DMUs
100	8
90–100	6
80–90	13
70–80	7
60–70	13
>60	13
Total No. of DMUs	**60**

We found that when we keep the inputs fixed, in order to achieve full efficiency in police stations, most of the improvements needed were in the logistic outputs 16, and 8 – the overall average improvement needed are 13%, and -9% respectively. However, if we keep the outputs fixed, then, the improvement needed in personnel and cars are 9% and 11% respectively (i.e. we need to reduce both inputs to become efficient).

4.2. Stage 2 – Regression Analysis

Multiple regression analysis was applied to identify regional and urban factors affecting efficiency. Table 2 presents the regional and urban factors considered in the analyses.

Table 2 – Regional and urban factors considered

Regional variable	Units
Area	Square Kilometers
Population	Number of people
Vehicles	Number of population vehicles in the area
Minority population	Percent
Station Type	urban – 0, Rural – 1
District	A, B, C, D, E, F

As shown in Table 3, the multiple regression of BCC efficiency pointed out two significant environmental factors. These explain the variability of efficiency: vehicles (number of vehicles owned by the population in a given station jurisdiction area), and the region (southern).

Other environmental variables, which did not enter the regression, were: population size, type of police station (urban or rural), and other specific districts. The efficiency of a police station decreases as the number of vehicles increases. The indicator of the size is similar to the conclusions in other studies. However, in Israel, the southern region is more efficient than other regions. This region is mostly a desert land, although it is the largest region in Israel in area, it is the least in densely populated.

Table 3 – Regression coefficients where DEA efficiency score is the dependent variable

Independent variables	**Sign of the coefficient**
Vehicles	Negative
Southern region	Positive
Constant	80.3
R Square	0.303
P-value	0.012

4.3. Analysis by region

There are six regions in Israel. As shown in Table 4, the southern region (C) scored highest efficiency, while region B, which is the largest in dense population and vehicles, has the lowest average efficiency. It was found that region C is significantly *more efficient* than regions B, and F.

Table 4 – Efficiency: average scores – by region

Average	**A. North**	**B. Tel-Aviv**	**C. South**	**D. Judea & Samaria**	**E. Center**	**F. Jerusalem**
74.92	74.69	66.23	88.85	76.06	73.73	69.94

5. SUMMARY AND CONCLUSIONS

Measuring the efficiency of police service delivery can play an important role in achieving improvements in the performance of the police. Since there is no market contestability in police activities, the comparative performance analysis, given by DEA, introduces competitive pressure for police stations to improve. At the second stage, using regression analysis, the main explanatory urban factor for efficiency variability is the number of vehicles of the population in the station's jurisdiction area, namely, efficiency decreases with the increase of the number of vehicles (belonging to the population) in the jurisdiction area of the station.

The secondary factor is the region of the station – the southern region is more efficient than other regions. Other factors were not significant.

The significant explanatory variables are, in a sense, logistic factors. The results indicate that for fair comparability among police stations, there is a need to divide them into at least two groups by *size* (as reflected in the number of vehicles of the population). Other researchers in other countries (e.g. in USA [10] and in UK [6]) had similar findings regarding the effect of *size* on police efficiency. The hypothesis of some police commanders – that *the type of population (minorities, rural/urban, region) effects efficiency is false.*

For future research there is: a need to account for more types of police station inputs, and, there is a need to divide the stations into 2 groups – according to the number of vehicles belonging to the population in the jurisdiction area of the station.

6. REFRENCES

[1] Charnes, A., Cooper W.W., Rhodes E.: *Measuring the efficiency of decision making units*, EUR J OPER RES, 2(1978), 429–444.

[2] Garcia-Sanchez, I.M.: *Evaluating the effectiveness of the Spanish police force through data envelopment analysis*, EUR J LAW ECON, 23(2007), 43–57.

[3] Garcia-Sanchez, I.M., Rodriguez-Dominguez L., Parra-Dominguez J. P.: *Yearly evolution of police efficiency in Spain and explanatory factors*, CEN. EUR J OPER RES, 21(1)(2013), 31–62.

[4] Cooper, W.W., Lawrence M.S., Joe Z.: *Handbook on data envelopment analysis:* International series in operations research & management science, Kluwer Academic, Boston, 2004.

[5] Thanassoulis, E.: *Assessing police forces in England and Wales using data envelopment analysis*, EUR J OPER RES, 87(1995), 641–657.

[6] Drake, L., Simper R.: *The measurement of police force efficiency: An analysis of UK home office policy*, Contemporary Economic Policy, 23(2005), 465–482.

[7] Banker, R.D., Charnes A., Cooper W.W.: *Some models for estimating technical and scale inefficiencies in data envelopment analysis*, Management Science, 30(1984), 92–1078.

[8] Allen, R., Athanassopoulos A., Dayson R.G., Thanassoulis E.: *Weights restrictions and value judgement in DEA: Evolution, development and future directions*, ANN OPER RES, 73(1997), 13–34.

[9] Banxia Software, http://www.banxia.com/frontier/

[10] Gorman, M.F., Ruggiero J.: *Evaluating US state police performance using data envelopment analysis*, Production Economics, 113(2008), 1031–1037.

[11] Sinuany-Stern, Z., Alper D.: *Efficiency of cars vs. Manpower in police stations*, Proceedings of International Conference of Industrial Logistics, 2012, 392–397.

VALUE ADDED HEAT MAP – A NEW METHOD FOR THE OPTIMIZATION OF PRODUCTION SPACE

Dagmar Piotr TOMANEK[1,2], Jürgen SCHRÖDER[3], Markus WIRZ[4]

[1]University of Bayreuth, Graduate School
Universitätsstraße 30, 95447 Bayreuth,
Germany
[2]Technische Hochschule Ingolstadt,
Zentrum für Angewandte Forschung (Research Center),
Esplanade 10, 85049 Ingolstadt,
Germany
[23] Technische Hochschule Ingolstadt, Business School
Esplanade 10, 85049 Ingolstadt,
Germany
[4] wilogs – Wirz Logistics Support
Buchenstraße 8a, 84169 Altfraunhofen,
Germany

Abstract:

The VAHM (Value Added Heat Map) is a visualization tool that indicates the level of value creation concerning production relevant factors like space usage. Common methods for the evaluation of added value, e.g. Value-Stream Mapping or Sankey-Diagram, are inadequate concerning the rating of production spaces. The VAHM approaches an integrated assessment of the named factor. In this article the innovative VAHM method is described and applied as a model to a production shop floor. It is a practical basis for optimizing a production layout to generate smaller area with the same value.

Keywords:

Value Added Heat Map, VAHM, Value Creation, Value Added Concentration, Production Space Efficiency

1. INTRODUCTION

1.1. Value Added Concentration

According to Womack and Jones, the value of a product or a service is defined by the customer [1]. Finkeissen summarized the term Value Added as all activities, which create the value of a product in relation to customer benefit [2]. Consequently, all activities that are not creating value are to be seen as wastage, which should be reduced or eliminated. Wastage is the share of creation effort that the customer is not willing to pay for [3].

An approach to assess the Value Added is the analysis of the Value Added Concentration. The Value Added Concentration negatively correlates to wastage. The less wastage occurs within a process the higher is the VAC. The same applies vice versa. Relevant factors for assessing the Value Added Concentration are personnel deployment, resource usage as well as space usage

[4,5]. A maximum utilization of the personnel, which is participating in the value creation, is expedient because they perform the actual creation of products or services.

In order to concentrate the Value Added, these staff members should focus their working capacity solely on their core tasks. Optimization of the resource usage, e.g. equipment or machines, should also be pursued to ensure the concentration of added value. Spaces within the shop floor are usually highly limited. Supporting logistic processes like the provision of material use such limited spaces. Reserved material only create limited value. They cannot be eliminated completely, but at least be minimized. Reducing spaces which do not create value, to ensure that sufficient space for the actual value adding process is available, should be the primary aim.

Methods for analysing and assessing the added value of processes have already been designed. In the following, the Value-Stream Mapping as well as the Sankey-Diagram methods will be discussed.

1.2. Value-Stream Mapping

Value-Stream Mapping is a proven method for identifying and avoiding wastage within a production process. It was originally developed in the 1990's in the course of the Toyota production system. Today, it is also used in other industries for process improvement [6].

A Value Stream is the combination of all activities, which are required for processing a product from its initial to its final stage that is desired by the customer [7]. Wherever a product for a customer is, there also exists a Value Stream [8]. A Value-Stream Map captures the current state of the production process in the form of a Multi Moment Recording, which is a sampling procedure for determining the frequencies of occurrences of predefined phenomena [9]. Defined components, which are recorded are the customer, the supplier, the production- and business processes as well as the flows of materials and information. Specific values can be assigned to each of these components in order to enhance the conclusiveness of the map.

In order to draft a Value-Stream Map, four steps are necessary. The definition of product families; the analysis of customer needs; the recording of the Value-Stream within the production; as well as identifying and visualizing improvement potentials within the Value-Stream [10]. An important element in this model is the lead time. It consists of the actual processing times of the different production steps and the timeframes in between these processing times [11]. To assess the value creation, this method uses a Value Added coefficient. It shows which share of the total lead time is taken up by the actual processing time [12]. Thus, it also shows which part of the lead time is not used for value creation.

In conclusion it can be said that Value-Stream Mapping is a pure analyzing tool. The used nomenclature allows a simple but complete graphic representation of the whole production process from a bird's-eye perspective. The quick identification of occurring wastage as well as the enhancement of the overall transparency make this tool especially valuable [10].

1.3. Sankey-Diagram

The Sankey-Diagram is an analyzing tool that can be used to visualize the flow of materials, energy or costs. It consists of two main components, the individual process steps and arrows. The arrows interlink the occurring process steps and the direction of the different flows. The arrow's thickness represents the quantity of the substance which occurs in the flow [13].

The Sankey-Diagram had originally only been used for thermodynamic systems, but was then successfully applied to different disciplines [14]. In thermodynamics, heat losses could be identified with this tool. Applied in a production plant it can be used to identify material losses, for instance by production faults or inefficient processes. Thus, in industrial management, it provides a needs-based design of material flows.

A Sankey-Diagram only visualizes substances that actually occur in a flow. In a production context, these would be e.g. the materials in between the goods receipt and the goods issue. Stocks at a warehouse or at the individual workplaces are not included [15].

The drafting of a Sankey-Diagram starts with recording the flows of the occurring substance within the analyzed subsystem. With production bills of materials as well as work plans, the sequence of the process steps are derived. Additionally, the production quantities are assigned to the relevant processes. The quantitate relations are then recorded. Usually, a matrix which covers start and end points as well as the frequencies and volumes are used for that purpose. The finished matrix may then be converted into a Sankey-Diagram. The numeric values in the matrix determine the thickness of the visualized arrows [16].

The visualization of this diagram can be combined with a factory layout. This would result in a correct special assignment of process steps and material flows. The simple, model-like format of the Sankey-Diagram allows for a practical assessment of the regarded system concerning its value creation. Within a production plant the Sankey-Diagram can e.g. display crossing material flows, which cause production backlogs. Transport bottlenecks or material loops are further examples that can be displayed with this tool. Consequently, waiting times in the production could be explained.

The finished Sankey-Diagram can be the basis for deriving measures for improving the added value. Rearranging the production layout and the workplaces can result in reduced transport routes and less transport vehicles [13]. Additionally, positive effects can be achieved concerning total quality, personnel ergonomics, the economic efficiency as well as the environment [17].

2. METHOD DESCRIPTION – VALUE ADDED HEAT MAP

The theoretical foundation for drafting a VAHM (Value Added Heat Map) is the previously described concept of Value Added Concentration. Widely known methods for evaluating the value creation are Value-Stream Mapping or the Sankey-Diagram. In contrast to these two methods, the VAHM focuses on other value-related aspects of the production process, like the usage of space. The Value Added Heat Map is a visualization tool that may be a useful complement to Value-Stream Mapping or the Sankey-Diagram. It facilitates the evaluation of value creation aspects and additionally visualizes occurring wastage.

2.1. Evaluation of Production Space

The main purpose of the VAHM method is to visualize production relevant aspects with regard to their value. The following descriptions will be about the usage of space.

In production and service companies, the proportionate costs per square meter or comparable rental costs are considered for the economic assessment of spaces. There is normally no distinction made between the value and a square meter has in relation to the production plant and the necessary infrastructure. This often results in an insufficient analysis of the existing layouts and those that are to be planned anew. Potentials to further concentrate spaces or to provide a more practical plant layout cannot be realized.

In the VAHM method spaces have different values. Spaces that are used for actual value creation, e.g. with production plants, are considered especially valuable. There are also spaces which are not directly used for value creation, but which necessary for operating the plant, like staging areas for required materials, spaces for intermediates and finished goods or transport routes for reaching the plants. These spaces only have limiteded value added contribution. Spaces that are not used at all do not contribute to value creation.

The prior aims of the VAHM are to visualize the value creation level of spaces using a color scaling and to assign a conclusive key performance indicator for facilitating comparison. The graphical result of the analysis resembles a thermal image, therefore it is called Value Added Heat Map. Potentials for improvement can easily be recognized.

The VAHM can be used as the basis for deriving a series of measures that may improve the usage of the available space. As a consequence, investments in buildings or the rental of production or logistic spaces may be avoided. Alternatively, new plants could be integrated into the existing factory. The overall productivity on production spaces could be enhanced and costs reduced.

2.2. Evaluation Scale for Space Usage

Concerning the space usage, it is important to note that different spaces contribute differently to the added value. As shown in the left-hand column of Table 1, the three main categories for the space usage are “no added value”, “limited added value” and “maximum added value”. The middle column shows a possible way of organizing the Value Creation Levels with colors and numeric values. In the right-hand column, criteria for each scale value are defined. Production spaces in which production lines are classified as having maximal added value “8”. Spaces that are not used and are not accessible have “no added value” and are to be assessed “0”.

The driveways within a factory can be compared with the blood circulatory system of a human. They serve the purpose of providing required materials and are important for the production personnel to reach their workplaces. Factors like safety, corporate design or the historically grown infrastructure are to be considered while planning or optimizing driveways. These are some reasons why it is recommended to assess driveway spaces as “neutral” within a VAHM.

The lowest level of added value “no added value” considers spaces that are neither accessible nor used. These areas are e.g. used for storing defective parts or empty containers. These kinds of spaces are to be categorized “0”, as they have to be cleared with physical effort before being ready for use. Areas for defective parts are, if possible, to be located in the logistics area but in not within the shop floor. Spaces for empty containers can be minimized if they are carted away each time new materials are supplied.

A very high potential for improving the value added hold unused spaces, which are freely accessible but unused. They are to be classified with a Value Creation Level of “1”. In contrast to spaces with a value of “0”, these spaces can directly and without physical effort be used for creating value.

Staff wardrobes, meeting and recreation as well as office spaces that are within the shop floor are not value creating in the strict sense. But they are necessary, because they enable the personnel to hold short meetings and to take a break. Depending on the size of the factory, there may be no alternatives to establish these kinds of rooms outside the shop floor. This is why these spaces are valued “2”.

Table 1 – Evaluation Scale for Space Usage

Categorization	Value Creation Level	Dimension Space Usage
Neutral	-	To be classified as neutral - usually driveways that are used by industrial cargo trailers to ensure material supply.
No Added Value	0	Unused area (not accessible and unused) and areas for empties, waste and blocked defective parts.
Limited Added Value	1	Unused space (accessible but unused).
	2	Meeting and recreation rooms, staff wardrobes and office space on the shop floor.
	3	Area with semi-finished products and finished products as well as material staging areas more than 5 meters away from the workplace.
	4	Material staging area 1-5 meters away from the workplace.
	5	Material staging area surface max. 1 meter away from the workplace.
	6	Workplace (administrative) of the production personnel on the production line.
	7	Workplace (operative) of the production personnel at the production line.
Maximum Added Value	8	Production line (e.g. machines, robots, etc.).

Material flows within the shop floor do not directly contribute to the added value, but are necessary to enable value creation in the first place. The flow of material leads to stocks that consequently consume space. The closer required material is brought to the workplace, the more efficient the personnel can work when looging at their required movements. Consequently, the levels of value creation for the material staging areas are dependent on the distance to the location of usage. Material stages which are more than five meters away from the workplace have a Value Creation Level of “3”. This level also includes intermediates and finished products that are the output of a process step. Their value creation level is always “3”, as their distance to a workplace does not matter. Their usage usually takes place at another location.

A Value Creation Level of “4” are material stages, which are located between a radius of one and five meters from the actual workplace. While the production personnel can easily reach the required materials, leaving the workplace is still needed for a continuous value creation.

Material stages with a distance of less than one meter from the workplace are to be considered level “5”. This most efficient and optimal form of providing material is present, if the production personnel does not need to leave their workplace in order to perform their core tasks. In this situation the personnel can avoid inefficient tasks, which do not create value, like gathering required materials. Consequently, materials should be directly provided at the workplace to ensure a maximal utilization of the production personnel. It is to be noted however that spaces at workplaces are highly limited.

The actual workplaces have a high level of value creation. The VAHM model distinguishes between administrative and operative workplaces of production staff. Administrative workplaces include required spaces for computers, printers, desks or access opportunities. They can be seen as an interface between the personnel and the production control and therefore serve administrative purposes within the shop floor. These spaces have a value creation level of “6”. The workplace of an operative employee, who is e.g. required for the assembly of a product at a plant, has a value creation level of “7”. The only thing creating more value than an operative workplace are plants, e.g. machines or production robots, which create maximum value. Thus a plant has a Value Creation Level of “8”.

2.3. Survey description

To draft a Value Added Heat Map, a current layout of the analyzed shop floor is required. This serves as the basis for the assessment of the production space. In the next step, the size of one spatial unit needs to be defined. The authors recommend using one square meter, as it easy to measure and spatially imagine. Smaller or bigger units can defined as well.

In a spreadsheet application (e.g. Microsoft® Excel) it is possible to integrate the production layout as a background. It is advisable to adjust the dimensions of each cell within the application true to scale, e.g. so that one cell will represent one square meter. Based on a Multi Moment Recording on the shop floor each grid or square meter has to be determined according to the evaluation scale for space usage (see Table 1).

In the next step, the determined Value Creation Levels for each square meter have to be inserted into the spreadsheet application. The Value Added Heat Map for the factor space usage is supplemented by the key performance indicator “Value Added Density”. The Value Added Density indicates to which percentage degree the production spaces create added value (see Equation (1) – Key Performance Indicator “Value Added Density”).

$$ValueAddedDensity = \frac{\sum_{i=1}^{N} grid \times ValueCreationLevel}{N \times \max(ValueCreationLevel)} \times 100 \quad (1)$$

grid $i = 1, \ldots, N$,

N – amount of analysed grids

2.4. Results

The authors applied the VAHM method at a production facility of an automotive supplier. One single production line was analyzed with said method. The resulting Value Added Heat Map for this single production line is shown in Figure 1. It displays the color scaling as well as the relative to Value Creation Levels. The driveways surround the analysed shop floor. They are represented in the visualization with white colored cells but not in the calculation for Value Added Density.

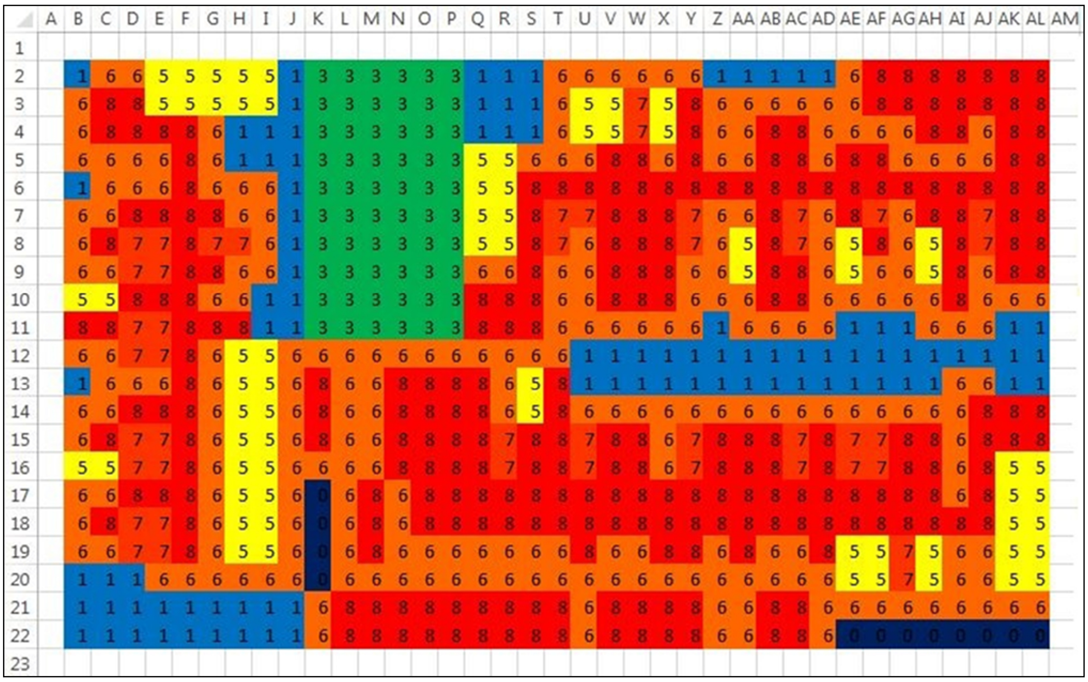


Figure 1 – Example of a Value Added Heat Map for a Single Production Line Analyzing the Space Usage

The shop floor of the analysed single production line area is 777 square meters. 33% of the area are maximum value added and classified as an "8". This corresponds to 258 square meters. 44 square meters (6%) are classified with the Value Creation Level of "7". 241 square meters (31%) is equal to level "6", 68 square meters (9%) to level "5", 60 square meters (8%) to level "3", 94 square meters (12%) to level "1" and 12 square meters (2%) to level "0". The Value Creation Levels "4" and "2" are not identified in this production line. The calculated Value Added Density for the VAHM in Figure 1 amounts to 71% which is relatively high. Consequently, the improvement potentials were few and the company in the study decided not to take action.

The same single production line was analyzed a second time, after a rearrangement of the production space due to increasing demand. The VAHM method was then used again by the supplier in order to analyze how the rearrangement measures impacted on the value creation. According to the supplier's calculations, the Value Added Density declined significantly. With the Value Added Heat Map the improvement potentials of the rearranged production line were visualized.

The VAHM method was deemed to be a very practical tool for monitoring the value creation in real-life situations. As a consequence, this method was applied to all production lines on the supplier's shop floor. Inefficiencies and improvement potentials were identified and measures were taken accordingly.

3. CONCLUSION

3.1. Optimizing the Production Layout

Through the application of the Value Added Heat Map, insufficiently used areas are visualized. This visualization can be used to form the basis for the optimization of the production layout.

14% of the space in Figure 1 is unused area classified with "0" or "1", which can immediately be used for value creation. 39% percent of the area is highly value adding and is classified with "7" or "8". The Value Added Density of 71% in the shown example implicates that on average 29% of the analyzed space can be optimized. More added value can be generated with less space used. This can, for example, be achieved by:

1. Space-concentration through an optimized arrangement of the production line and
2. Optimized arrangement of the supply areas to achieve shorter distances for the production personnel.

In practice a Value Added Density of 100% cannot be achieved. A production line, which solely uses highly value adding machines and robots is still a utopia. Furthermore it's neither required nor reasonably necessary. Buffer storage of raw material, operational workplaces or storage of finished goods at the production line is essential for having a functioning production system. In the opinion of the authors, the optimum Value Added Density lies between 70% and 80% and depends on the automatization degree present on the production line. In order to determine an optimal Value Added Density, benchmark tests seem appropriate.

The idea of having an area with only value adding machines and robots is still utopian. The authors believe the optimum lies between 70% and 80% and depends on the degree of the automatization in the production line. To determine the optimum Value Added Density benchmark tests seems to be advisable and appropriate.

3.2. Benchmark

The Value Added Heat Map method can be used to benchmark the value creation of different production layouts and also in service companies. The benchmarking could be carried out for a single production line or for a whole factory. It can be also used to compare space usage from various plants from one company too. An industry-wide or cross-industry comparison would also be possible.

3.3. Transfer to other Production Relevant Factors

The VAHM methodology can be applied to factors other than just space usage. Asset utilization, material stock or the exchange of information are some examples for factors that can be assessed and then visualized. On a business process map, inefficiencies in the flow of information and unnecessary or costly processes could also be visualized. Especially with regard to digital transformation, this method could be of great use to identify the aspects of networking which hold the greatest potential for improvement.

Possible examples to apply this method could be the production process of companies within the automotive industry or the interlinking of data and information in the healthcare sector.

4. REFERENCES

[1] Womack, J.P., Jones D.T.: *Lean thinking: Ballast abwerfen, Unternehmensgewinne steigern*. Frankfurt am Main, New York: Campus-Verl., 2004.

[2] Finkeissen, A.: Prozess-Wertschöpfung: Neukonzeption eines Modells zur nutzenorientierten Analyse und Bewertung. Heidelberg: A. Finkeissen, 1999.

[3] Bergmann, L., Lacker, M.: *Denken in Wertschöpfung und Verschwendung*. In U. Dombrowski, C. Herrmann, T. Lacker, S.Sonnentag (eds.), *Modernisierung kleiner und mittlerer Unternehmen: Ein ganzheitliches Konzept*, Springer Berlin Heidelberg, Berlin–Heidelberg 2009.

[4] Schröder, J., Tomanek D.P.: *Wertschöpfungsmanagement: Grundlagen und Verschwendung*, Workings Papers der Hochschule Ingolstadt 24(2012), 21–25.

[5] Woratschek, H., Roth S., Schafmeister G.: *Dienstleistungscontrolling unter Berücksichtigung verschiedener Wertschöpfungskonfigurationen — Eine Analyse am Beispiel der Balanced Scorecard*. In M. Bruhn B. Stauss (eds.), *Dienstleistungscontrolling: Forum Dienstleistungsmanagement*, Gabler, Wiesbaden 2006.

[6] Koch, S.: *Einführung in das Management von Geschäftsprozessen: Six Sigma, Kaizen und TQM*. 2nd ed.: Springer Berlin Heidelberg, Berlin–Heidelberg 2015, 137–143.

[7] Klevers, T.: *Wertstrom-Mapping und Wertstrom-Design: Verschwendung erkennen - Wertschöpfung steigern*. Landsberg am Lech 2007.

[8] Rother, M., Shook J.: Sehen lernen: *Mit Wertstromdesign die Wertschöpfung erhöhen und Verschwendung beseitigen*. 1st ed. LOG_X, Stuttgart 2000.

[9] Maasz, J., O'Donoghue J.: *Real-world problems for secondary school mathematics students: Case studies*, Sense Publishers, Rotterdam–Boston 2011.

[10] Erlach, K.: *Wertstromdesign: Der Weg zur schlanken Fabrik*, Springer-Verlag Berlin Heidelberg, Berlin–Heidelberg2010, 32–36.

[11] Wöhe, G.: *Einführung in die allgemeine Betriebswirtschaftslehre*, 20th ed. Vahlen, München 2000.

[12] Lindner, A., Richter I., Becker P., Göhner H., Maier R.: *Wertstromdesign*. 2nd ed. Hanser, München 2016.

[13] Klepzig, H.-J.: *Working Capital und Cash Flow: Finanzströme durch Prozessmanagement optimieren*, 3rd ed. Imprint: Gabler Verlag, Wiesbaden 2014, 86–98.

[14] Sankey, H.R.: *The thermal efficiency of steam-engines. (including appendixes)*, Minutes of the Proceedings 125 (1896), 182–212.

[15] Kamiske, G.F.: *Handbuch QM-Methoden: Die richtige Methode auswählen und erfolgreich umsetzen*, 2nd ed. Hanser, München 2013.

[16] Schulte, C.: Logistik: *Wege zur Optimierung der supply chain*, 5th ed. Vahlen, München 2009.

[17] Morghen, D.: *Industriebetriebslehre: Grundlagen; mit ... Tabellen*. Braunschweig–Appelhans 2010, 77–155.

SEQUENCING OF SINGLE PRODUCT OPERATIONS WITH MULTIPLE TECHNOLOGICAL CRITERIA

Maja TRSTENJAK[1], Predrag COSIC[2]

[1,2]University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
Ivana Lucica 5, Zagreb,
Croatia

Abstract:

Operation sequencing as part of manufacturing process planning is often understood as simple, but in reality it is complex phase in product lifetime that can have effect on overall cost and manufacturing time. There are several algorithms available, but their use is complex and they require the deeper knowledge in the area of machining and programming as well. Since operation sequencing can be understood as a decision making process, help of decision support systems can be used. One of them is the AHP method implemented in Expert Choice software. On the example of production of a simple rotational symmetrical product, the results of the use want to be analyzed in this paper.

Keywords:

operations sequencing, analytic hierarchy process, Expert Choice, decision support

1. INTRODUCTION

Main goal of every Operations Management and operational research [1] activity is to optimize given process. There are many methods for process optimization and they are usually based on various mathematical methods. They can be more or less complex, but the final result should be optimum or at least close to optimum, which would be satisfying for the user. Many phases and activities in product lifetime should be optimized one of them is operation sequencing. The order of operations during production process should be made as close to optimum as possible, or even optimal if possible.

2. OPERATIONS SEQUENCING AS DECISION MAKING PROCESS

Although there are several available methods for operation sequencing available, traditional approach is most common used and is based only of the knowledge and intuition of the process planner [2,3,4]. Human factor is very influential, and gap between CAD and CAM that should be covered with CAPP didn't deal with such situation [5]. Order of operations is most of the times based on technical possibilities of the given product. Apart from product features, price is very important factor, so sometimes process planner performs cheapest order of operations, whose quality and time demands aren't always optimal or minimal. Followed by his own knowledge, process planner makes simple decision of which operation should be performed first and which one should follow. In everyday situations, whether it is about business or manufacturing, there are many decision support systems available, one of them is AHP method (Analytic Hierarchy Process) [6] implemented in Expert Choice software [7], which will be used for operations sequencing on case study for production of an axle.

3. CASE STUDY – AXLE

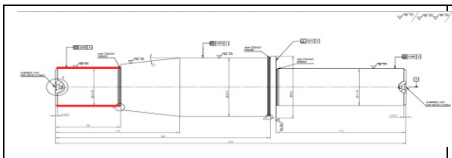
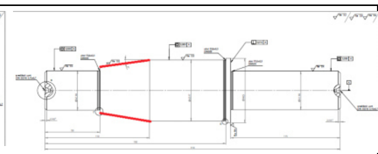
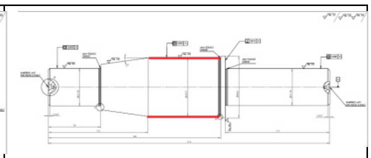
The axle that should be produced is shown of Figure 1. The demanded operations are turning, drilling and grinding. They are shown in Table 1 with drawings of surfaces in which they should be performed. In Table 2 the fixation methods are shown according to which the operations defined in previous stage are to be performed. In Table 3 final required operations by fixation position with preparatory (t_{pz}), auxiliary (t_p) and technological time (t_1) that has been defined in previous phase of process planning.

Those times will be considered in AHP method as quantitative criteria. Operations are the alternatives in AHP process.

4. PROBLEM STRUCTURING

The problem is being structured (Table 4) with help of the brainstorming process involving experts in the field of process planning. To eliminate the brainstorming disadvantages, the nominal brainstorming technique could be considered [8]. The processing operations with their parameters are already known and considered as some sort of input in the overall decision asking process. Regarding that, the criteria with the sub-criteria are being structured. The criteria listed in Table 4 are part of the problem structuring.

Table 1 – Required operations and surfaces [9]

		
Longitudinal turning Head-turning Drilling Grinding	Longitudinal turning Turning contouring	Longitudinal turning Turning contouring

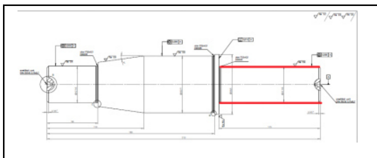
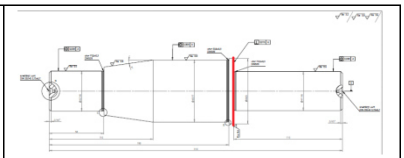
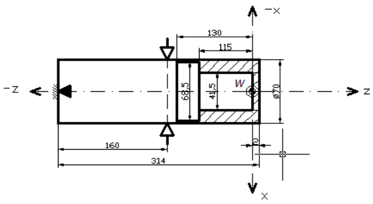
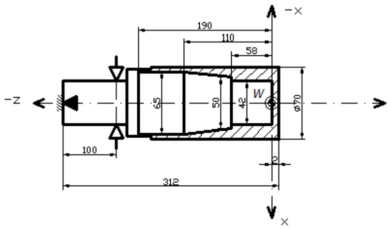
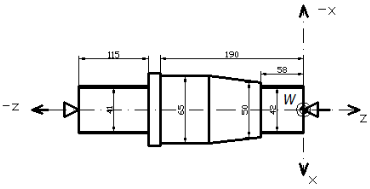
	
Longitudinal turning Head-turning Drilling Grinding	Head-turning

Table 2 – Fixation methods [9]

		
Fixation 1	Fixation 2	Fixation 3

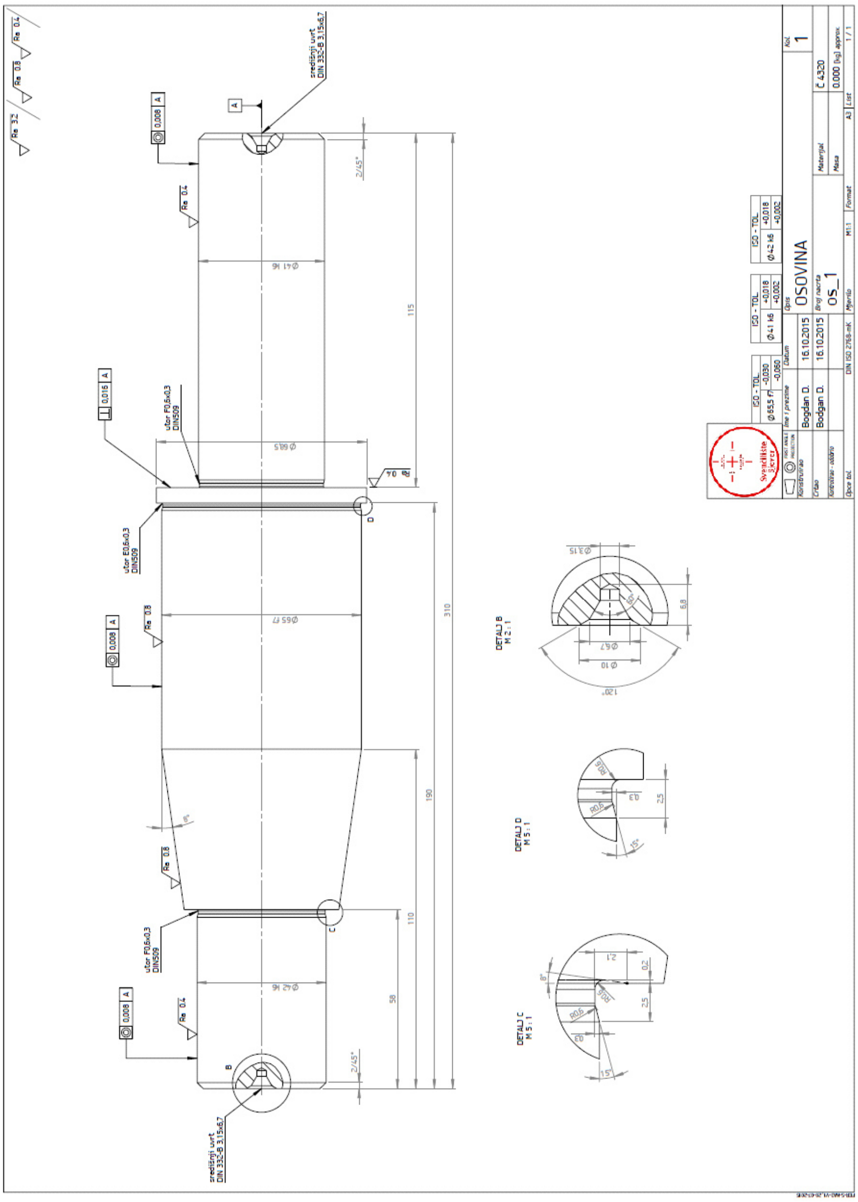


Figure 2 – Axle – technical drawing [9]

Table 3 – Operations/alternatives [9]

Operations	Machine	t_{PZ}, min	t_p, min	t_1, s
FIXATION 1	Machine tools centre	30		
Head-turning 1			0,23	15
Longitudinal turning 1			0,5	30
Turning contouring 1 (fine)			0,2	40
Drilling 1			0,2	36
FIXATION 2	Machine tools centre	30		
Head-turning 2			0,23	15
Longitudinal turning 2			0,5	45
Turning contouring 2 (fine)			0,2	50
Drilling 2			0,2	36
FIXATION 3	Grinder	30		
Grinding fi42k6			0,6	45
Grinding fi41h7			0,6	50

Table 4 – Criteria

TECHNOLOGICAL CRITERIA	PRODUCT CRITERIA
operations number	process priority
tool change number	quality
technological time	surface protection
auxiliary time	material
tool wear	working space size
fixation type number	probability of failure
cutting speed	surface quality demands
cooling lubricant	product functionality
critical speed with consequences	
ECONOMICAL CRITERIA	**ERGONOMIC CRITERIA**
productivity/hour	human needed
tool price	availability
working hour price	manipulation possibility
process price in product price	overall process control
labor price	
PROCESS CRITERIA	**ECOLOGICAL CRITERIA**
possibility of automatization	energy efficiency
number of machines in process	cooling lubricant toxicity
possibility of modification	separate parts number
internal transport	
organization	

As it can be seen, the sub-criteria have been structured in several groups – main criteria – technology-based, economically-based, product-based, ecology- and ergonomics-based criteria.

Roughly, the criteria can be divided in two groups – qualitative and quantitative criteria. The quantitative criteria are the ones for which numerical information is available and they are processed in an objective way. There are many qualitative criteria for which are not completely clear how to analyze and compare them on objective way. They depend firstly on the knowledge of the process planner and are being compared pairwise on the scale 1 to 9, where 1 is equal importance and 9 is the biggest importance.

The criteria mentioned are structured widely with many different fields included in the operation sequencing process. They have to be considered, because they may not be directly connected to the order of operations, but they have influence in some way. Therefore, their importance is being evaluated. Technological criteria deal with machining process/operations defined in previous phase. Product criteria deal with product and its physical features which influence complexity of performance of operations. Economical criteria are based on cost and productivity, while ergonomic criteria are added to make problem wider and more complex, as well as ecological criteria. Process criteria deal with manufacturing process in the company and can be further used as an easy way for sensitivity analysis if there are major changes in automatization of process or if changes in organization occur and have influence on overall process.

5. NUMBER OF POSSIBLE VARIANTS OR ALTERNATIVES

There are ten alternatives. Number of permutations is 10! – 3 628 800 possible alternatives. At the very beginning, there are technical limitations for the operations sequencing. Firstly, fine operations should follow rough operations. There are six rough and four fine operations. Fine operations are divided in turning contouring and grinding. Grinding should come at the very end. Now there are 6! – 720 possible permutations of rough operations and four additional fine operations order – 724 operations. Another technical limitation is that drilling should follow head turning. Now there are 4! – 24 rough operations' permutations + 2 head-turning + 4 fine operations' permutations – 30 permutations available. Among 30 the optimal should be chosen, and that is advised to be solved using AHP method with various criteria mentioned.

6. RESULTS

After both alternatives and criteria have been evaluated in Expert Choice software, results are shown in Figure 2.

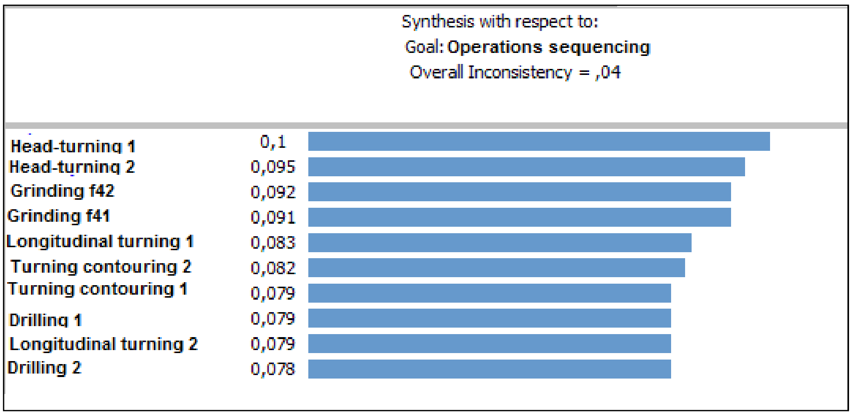


Figure 3 – Results – basic model

As operation that should be performed first head-turning 1 has been advised, followed by head-turning 2. Results have shown that grinding operations should be performed before turning which is not possible. That is why the critical approach is needed, or some model modifications/improvements must be made.

The problem of fine/rough operations' division and final order has been solved with addition of other criteria, very influential that makes immediate difference with fine and rough operations. It puts fine operations in the very end of the order. Everything else remained the same and has no influence on the final order because the ratio between old criteria and alternatives has remained the same.

The results are shown in Figure 3.

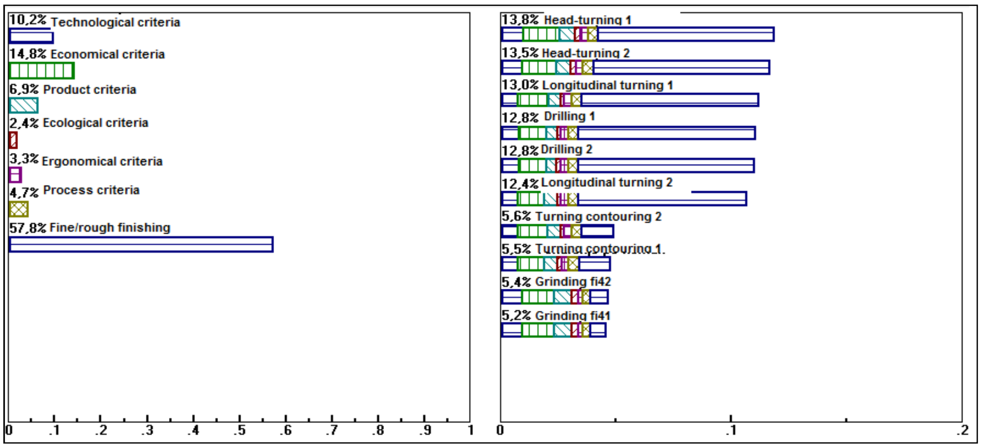


Figure 4 – Results – primary scenario

Now the order can be considered as the final one and it is following:

1. Head-turning 1
2. Head-turning 2
3. Longitudinal turning 1
4. Drilling 1
5. Drilling 2
6. Longitudinal turning 2
7. Turning contouring 2
8. Turning contouring 1
9. Drilling fi42
10. Drilling fi41

7. ALTERNATIVE SCENARIOS

Model verification was made by applying alternative scenarios based on various situations that can happen in everyday manufacturing process. First modification was shorter preparatory and auxiliary time, shown in Figure 3. This can be done by adding robot or automatization of certain part of the overall process. In this case productivity increases and working labor price decreases. Also, energy sufficiency increases. The adjustments were made on turning operations, and the preparatory and auxiliary times have been shortening for 20%.

Second scenario was based on pallet system and advanced fixation methods. By using newest technologies in this field, technological and auxiliary time is shorter, productivity increases and fixture criterion is being modified. Results are shown in Figure 4.

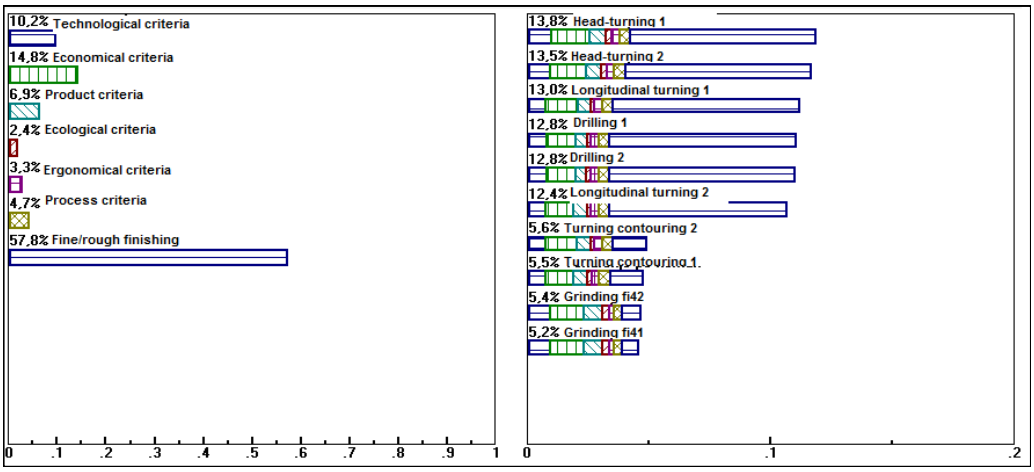


Figure 5 – Results – shorter preparatory and auxiliary time

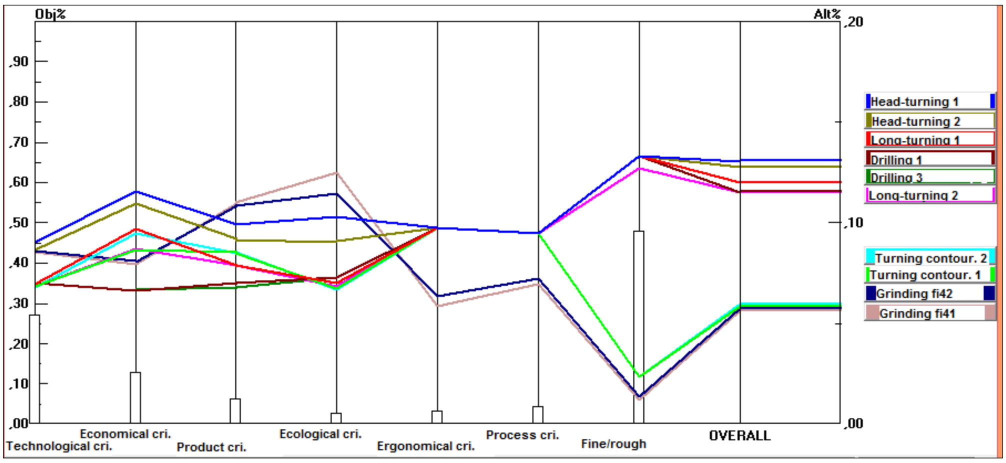


Figure 6 – Results – advanced fixation methods

In both cases, changes haven't been noticed; everything remained the same like in the first scenario. The reason for that is the relatively low influence of the modified criteria and significant influence of other criteria mentioned, weather they belong in same or other field.

8. EVALUATION OF RESULTS

The critical view on the overall situation is needed. The question is, is this order of operations really optimal or should some additional modifications be made. Method has proven that is possible to divide operations in fine and rough ones. Technical limitations have successfully being solved and the order was made according to them, but still, there are several fixture changes in the "optimal" order, which is not common in the real-life situations. This situation can be explained by model structure and that there are more criteria that go in favor of fixture change then the opposite ones. Overall model brings to conclusion that if there are modern machine centers available traditional way of thinking can be eliminated and with decision support system, AHP method in this case, optimum results can be made. Big advantage of use of AHP method is the fact that user defines and structures the problem be his own demands and unique situations.

9. CONCLUSION

Operations management deals with optimization of real-life problems in the various fields. One of the fields is manufacturing. Phase in product lifecycle that should be optimized is operations sequencing. Order of operations to be performed is influenced by various factors, including technological, economical, ergonomical, product and others. This can easily understood as decision making process and AHP method can be used. Expert Choice as software is easy option to deal with but the results need to be critically observed. Problem is being structured with criteria made by brainstorming process of experts, and operations are the alternatives. After every finished process, user should make a control are the results technically possible. If that is fulfilled, results can be considered as optimal, but only in theory. There is big influence of human subjectivity in overall process, and minimization of this factor should be considered in future research. Also, the use of the method is advised to be explored so it can be proven how this is easy way to define optimal order of operations.

10. REFERENCES

[1] Winston, W. Foldberg J.: *Operations Research: Applications and Algorithms*. Thomson Brooks/Cole, 2004.

[2] Gologlu, C.: *A costraint-based operation sequencing for a knowlege-based process planning*, Journal of Intelligent Manufacturing 15(2004), 463–470.

[3] Kafashi, S.: *Integrated setup planning and operation sequencing (ISOS) using genetic algorithm*, International Journal of Advanced Manufacturing Technologies, Springer, 2011.

[4] Nallakumarasamy, G., Srinivasan P., Venkatesh Raja K., Malayalamurthi R.: *Optimization of operation sequencing in CAPP using simulated annealing technique (SAT)*, International Journal of Advanced Manufacturing Techologies, 54 (2011), 721–728.

[5] Engelke, W.D.: *How to Integrate CAD/CAM Systems: Management and Technology*,. CRC press, 1987, 237–238.

[6] Saaty, T.: *Decision making with the analytic hierarchy process*, Int. J. Services Sciences 1(1)(2008).

[7] Expert Choice, http://expertchoice.com/, (06-01-2015.).

[8] Sikavica, P., Hunjak T., Begičević Ređep N., Hernaus T.: *Poslovno odlučivanje*. Školska knjiga, Zagreb 2014.

[9] Trstenjak, M.: *Decision support in assessment of operations sequencing*, Diploma work, FSB, Zagreb 2016.

CHARACTERIZATION OF MULTI-OBJECTIVE PERFORMANCE METRICS IN RELATION TO INVENTORY CONTROL STRATEGIES

Jiayi WANG[1], Jonathan EBNER Jr[1], John GERAGHTY[1]

[1]Enterprise Process Research Centre, School of Mechanical & Manufacturing Engineering,
DCU Dublin City University, Glasnevin, Dublin 9,
Republic of Ireland

Abstract:

This paper presents experimental work conducted on a theoretical three-stage tandem production line to investigate the influences the control parameters, of various production control strategies, have on determining an optimal strategy to minimise inventory while simultaneously minimising backlogged demand. The production control strategies considered were Kanban, Minimal Blocking, Hybrid Kanban-CONWIP and Hybrid Minimal Blocking-CONWIP. Complete enumeration of the decision spaces within prescribed ranges for the control parameters revealed the importance and direction of influence of each control parameter for each strategy. These insights will be useful for designing computationally efficient multi-objective optimisation algorithms for this class of problem.

Keywords:

Pull type control strategies, Multi-objective evolutionary optimisation, Serial lines, Multi-stage production systems

1. INTRODUCTION

Production control strategies are intended to manage authorisation cards for parts entry into a system and the inherent semi-finished goods flow among workstations. Pull type control strategies frequently present superior performance in inventory level control and general effectiveness in the presence of stochastic demand [1-3]. Comparison studies of well-known pull type control strategies including: Kanban, Basestock, Hybrid Kanban-CONWIP have been conducted and presented in the literature previously [3-5]. Only a limited number of publications present multi-objective approaches in production and inventory control optimisation.

Andijani [6] developed a decision support framework using a simulation model combining the Analytic Hierarchy Process (AHP) technique to determine the Kanban allocations where the total number of Kanbans was assumed to be fixed. Three performance metrics were considered; namely mean WIP (Work in Process), mean flow time and mean throughput. AHP was used to identify the most-preferred Kanban combination among the non-dominated front. The same approach is found in another study [7] to compare Hybrid and Kanban control strategies. In the literature, there are studies that either implement a multi-objective genetic algorithm (MOGA) alone [4, 8] or integrate a multi-objective algorithm as part of their optimisation method in order to explore the experimental space and locate the optimal solution set

[9,10]. The Strength Pareto Evolutionary Algorithm 2 (SPEA2) was used in [11] to compare Kanban, Basestock, CONWIP and Hybrid Kanban-CONWIP control strategies under two different manufacturing loads (light and heavy load) and two types of variances in machine processing time (high and low variance). WIP and Service Level were the performance metrics used in research works presented in [9,10]. Onyeocha, C.E, et al. [9] compared the performances of two production control strategies in multi-product manufacturing environments, namely Hybrid Kanban-CONWIP and Hybrid Basestock Kanban CONWIP (BK-CONWIP). Smew, et al. [9] compared the performances of simulation based optimisation using a MOGA with a Gaussian Process Metamodel optimised using the Desirability Function Approach to generate the Pareto front for a supply chain implementation of the Hybrid Kanban-CONWIP strategy. A MOGA was integrated with a regression model in [10] to improve the efficiency of the optimisation approach. The regression model was trained by using design of experiments and response surface methodology. During the MOGA optimisation process, regressions are integrated to maximise throughput and minimise WIP simultaneously.

None of this prior work has presented a complete enumeration of the decision space to provide evidence that the optimisation processes used found the true Pareto Front. The objective of this work is to explore the characterisation of the performance spread and investigate the impact on performance metrics as a result of changes in the number and distribution of production authorisation cards within a single product, multi-stage tandem production line. Full numeric simulation results for four pull type control strategies (Kanban, Minimal Blocking, Hybrid Kanban-CONWIP and Hybrid Minimal Block-CONWIP) are examined using the upper and lower Pareto fronts, the performance impact and the spread characteristics relative to the different control strategies. The goal for the MOGA is to address the trade-offs between average WIP and average backorder queue length.

Section 2 of this paper provides a brief overview of the production control strategies examined in this research. Section 3 provides details on the experimental procedure and the results of the experiments are presented and discussed in Section 4. Finally, Section 5 of this paper provides conclusions and directions for future work.

1.1. Pull type production line strategy

The primary objective of a pull control strategy is to improve a production system though inventory reduction by implementing a production control and work coordination mechanism reacting to actual demand rather than forecasted demand. This study uses multi-stage serial production lines for the simulation cases. Production lines in this study are subdivided into workstations consisting of a machine and buffers. The following section briefly explains the material flow and control strategies under investigation.

1.1.1. Kanban

Kanban control was originally developed in the Toyota production system to reduce and eliminate waste related to humans and resources [12]. Kanban systems have one buffer placed between two machines functioning as both the output buffer of the upstream station and the input buffer for the downstream station. When specific amounts of items stored in the finished goods buffer at the end of the production line are consumed to satisfy an order, the Kanban card detaches from the products, it flows back upstream and authorises the same amount of items to enter into the workstation to conduct its production activities. The detailed control mechanism is represented in Figure 1.

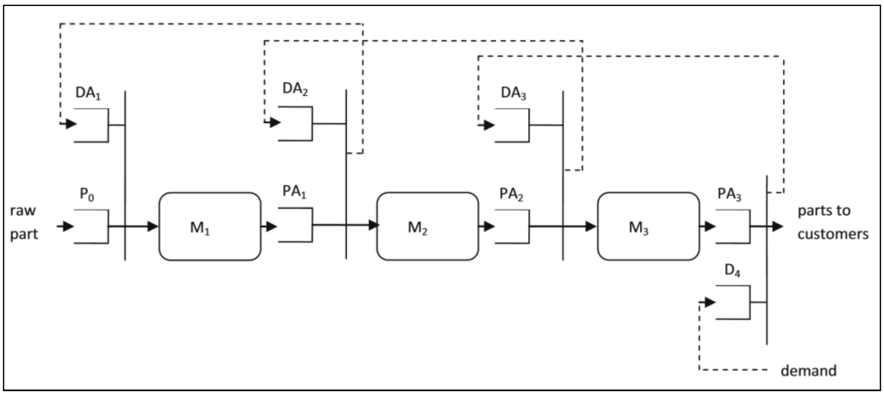


Figure 1 –A three stage Kanban system [4]

1.1.2. Hybrid Kanban-CONWIP

The Hybrid Kanban-CONWIP is a control strategy that combines Kanban and CONWIP, firstly proposed by Bonvik, et al. [3]. CONWIP in this hybrid strategy controls the overall number of WIP though the whole production line. Every production stage except the last one uses Kanban to control the inventory level to provide local (workstation) WIP control. The inventory of last stage is not controlled by any parameter and uses a push type control mechanism. The detailed control mechanism is represented in Figure 2.

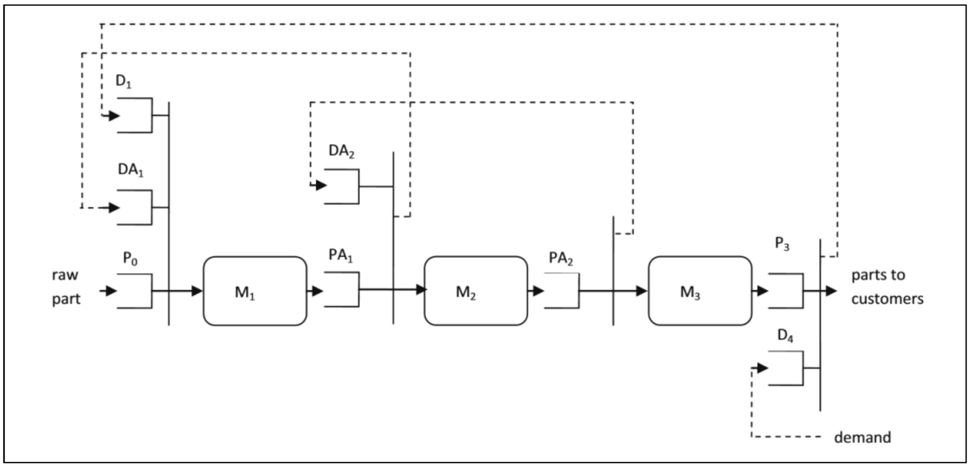


Figure 2 – A three stage Hybrid Kanban-CONWIP system [4]

1.1.3. Minimal Blocking

The logistics of material flow and authorisation cards for the Minimal Blocking and the Hybrid Minimal Blocking-CONWIP strategy are quite similar to the Kanban and Hybrid Kanban-COWNIP control strategies, respectively. The only difference between them is that each workstation consists of two buffers, an input buffer and an output buffer. Parts in a tandem Minimal Blocking model will be transferred to the downstream input buffer and the flow of parts downstream will not get blocked if the upstream station finishes the processing task before the downstream station becomes available provided that there are free Kanban cards at the downstream workstation [13]. The parts will simply move from the upstream workstation's output buffer to the downstream workstation's input buffer.

2. EXPERIMENTAL PROCEDURE

ExtendSim was used to develop a simulation model of a three-stage tandem production line, to which the different production control strategies were applied. The simulation models in this experiment are adapted based on the one used in [3,4] and validated by comparing results from the simulation models and the data in the literature [3]. This system produces a single product with three workstations where each workstation consisted of a machine and an output buffer. The production is necessarily passed through each workstation sequentially before it reaches the finished goods buffer. Product demand to the system follows an exponential distribution with mean of 1.01 min. Job size is set at 1, with no lead time. Therefore, an order will be satisfied immediately when there is a part available in the finished goods buffer, otherwise the demand is marked as backordered and stored in the backlog queue which uses a Fist Come First Served discipline. The queue for backordered demand has an infinite capacity. The processing time for each machine follows a lognormal distribution and is set to represent a high load situation where the mean processing time (mean = 0.71 min and standard deviation = 0.02 min) is slightly smaller than the mean order arrival time. Workstation 2 is assumed to be the bottleneck of the entire system which has a longer processing time than the other two workstations which is also modelled with a lognormal distribution (mean = 0.96 min and deviation = 0.02 min). All machines in the system have the same exponentially distributed mean time between failure time (mean = 1000 min) and exponentially distributed mean time to repair (mean = 3 min) for considerations of unexpected production disruption. The four pull-type control strategies are submitted for comparison in this experiment. The limit of parameters setting is confirmed by simulating them at two extreme conditions where all the authorisation cards are at lower or upper limits. The results indicated that enough exploration could be set by using the settings presented in Table 1.

Table 1 – Authorisation cards configuration

Strategy	Number of Kanban (for each workstation)	CONWIP
Kanban	1 to 20	-
HK-CONWIP	1 to 20	1 to 60
Minimal Blocking Kanban	1 to 20	-
Hybrid Minimal Blocking-CONWIP	1 to 20	1 to 60

The following are the simulation modelling assumptions for all strategies under investigation in this study:

1. No delay in transiting materials between workstations, Kanban cards communication is immediate.
2. All buffers in the system follow the first in first out rule and machines follow the first come first served policy.
3. Before a product enters a workstation, it needs to wait for an available authorisation card.
4. Any demand not satisfied will wait in a queue at the final production stage until matched by the finished good supply. The backordered demand will not stop demand creation, but will be satisfied before any newly created demands can be satisfied.

The simulation termination condition was that 100,000 orders are satisfied. There are in total 8,000 cases that needed to be executed for both Kanban and Minimal Blocking, and 24,000 cases for both of the hybrid strategies. This allows for the creation and exploration of the real Pareto front and the matrix spread type. Performances of all these cases are evaluated from simulation models at a single run as in the paper written by Xanthopoulos and Koulouriotis [4], each scenario in the space is simulated long enough to exclude the impact of the warm up period.

3. RESULTS AND DISCUSSION

The entire experimental space for the four control strategies was analysed thoroughly. Performance results for Minimal Blocking strategies data is plotted in Figures 3 & 4, detailing the output spread:

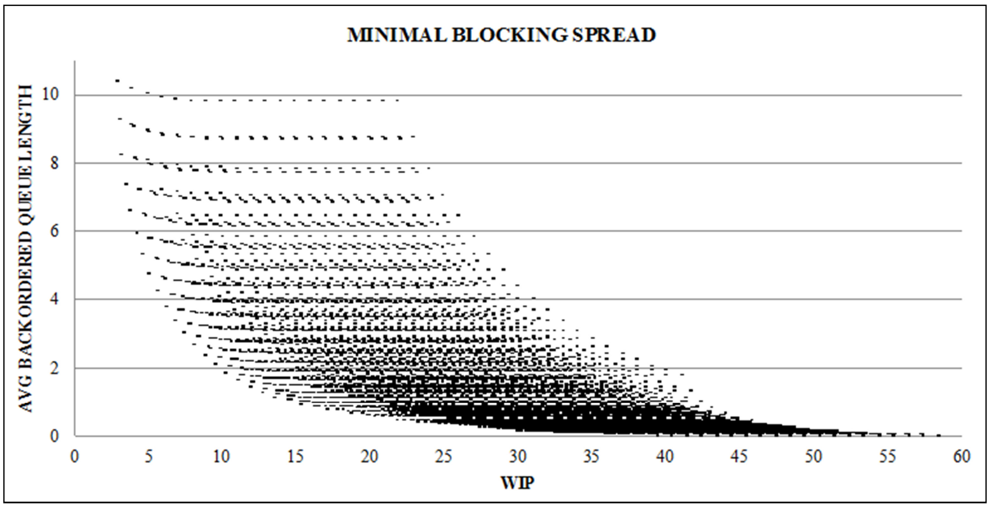


Figure 3 – Minimal Blocking Strategy – Performance Spread

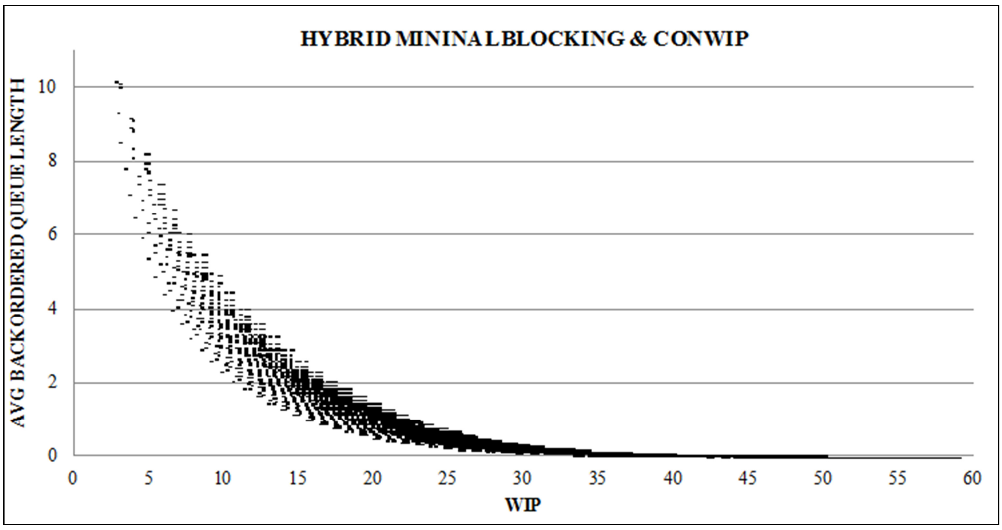


Figure 4 – Hybrid Minimal Blocking-CONWIP Strategy – Performance Spread

From the above figures, it is possible to verify the overall nature of the performance points spread. It is found that the tested hybrid strategies consistently perform better with significantly lower variability and spread in relation to any other control strategy in the study.

Kanban and Minimal Blocking control strategies present a broad spread between the lower (optimum) and upper (worst case) performance limits. The performance points of the hybrid control strategies have a higher density and are more evenly spread. The upper and lower Pareto fronts describe in detail the system performance as depicted in Figure 5 below.

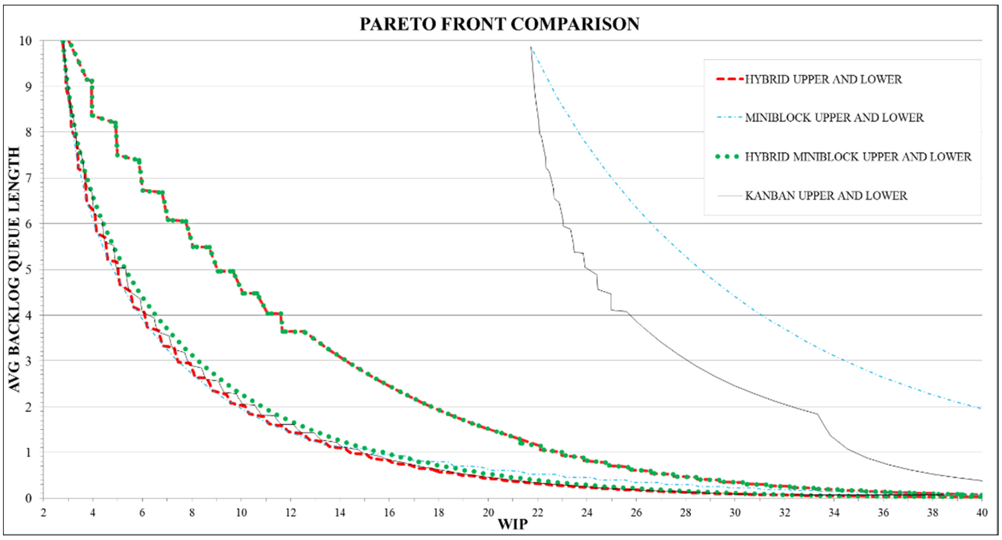


Figure 5 – Multiple Strategies Pareto Front Comparison

From Figure 5, it can be observed that:

1. When the decision maker has a preference for maintaining WIP at low values and is willing to accept higher backorder levels, Minimal Blocking Kanban performs as good as and often better than Hybrid Kanban-CONWIP. Additionally, Hybrid Minimal Blocking-CONWIP is the worst performer and Kanban is somewhere between Hybrid Kanban-CONWIP and Hybrid Minimal Blocking-CONWIP.
2. As the decision maker places more emphasis on minimizing the backlog (below 1 unit) Minimal Blocking Kanban becomes the worst performer and Hybrid Kanban-CONWIP the best performer, while Kanban is still better than Hybrid Minimal Blocking-CONWIP in terms of WIP required to achieve the desired backlog level
3. As the decision maker approaches requiring a strategy that will deliver a zero backlog level the Hybrid Minimal Blocking-CONWIP begins to outperform Kanban.
4. Both Kanban and the Minimal Blocking Kanban have significantly higher upper Pareto fronts than the two hybrid strategies.

From a multi-objective optimisation algorithm deployment perspective, the Hybrid Minimal Blocking-CONWIP strategy and, in particular, the Hybrid Kanban-CONWIP strategy would prove to yield significantly higher computational efficiency than Kanban and Minimal Blocking Kanban strategies. In some specific cases, the real Pareto front can be unknown due to the size of the experimental space. So, the Pareto front formulated by a multi-object optimisation algorithm could be a line between the upper fronts and lower fronts presented in the abovementioned figures. Both hybrid strategies in this study have the smallest area between the real upper and lower Pareto fronts. Therefore, there is a greater likelihood of obtaining a point near to the optimum Pareto front without the need to explore the entire combination along a large experimental space.

In order to investigate the impact of each of the types of authorisation cards on the performance metrics, Figures 6–8 present the impact of each card type in the Hybrid Kanban-CONWIP strategy and Figures 9–11 present the impact in the Kanban strategy.

In the Hybrid Kanban-CONWIP strategy, from Figure 6, it can be seen that for this system where the bottleneck is located at the second workstation maintaining the Kanban allocation to workstation 1 (Kanban1) as low as possible will minimize WIP. Additionally, from Figure 8, it can be seen that increasing the CONWIP level is necessary to minimize the backorder buffer size. Finally, from Figure 7, it can be seen that the Kanban allocation to workstation 2 (Kanban2) has no discernible impact on the performance metrics. That is to say that the lower Pareto front can be found by controlling the allocation of Kanban cards to workstation 1 and the number of CONWIP cards in the system, the number of Kanbans allocated to the second workstation is irrespective. A similar set of observations were drawn from investigating the Hybrid Minimal Blocking-CONWIP strategy.

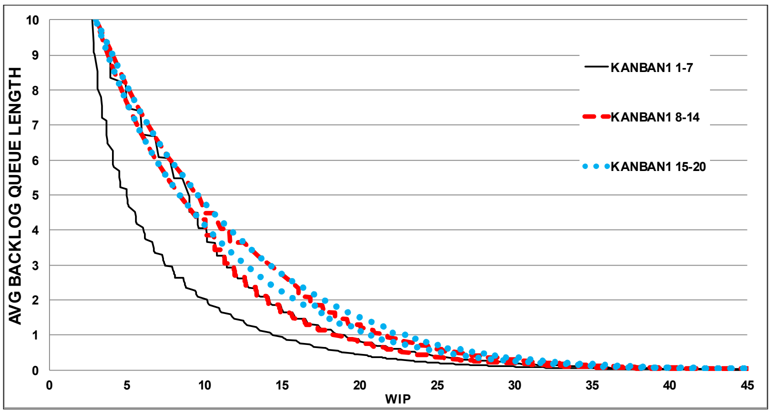


Figure 6 – Hybrid Kanban-CONWIP control strategy – Kanban 1 performance impact

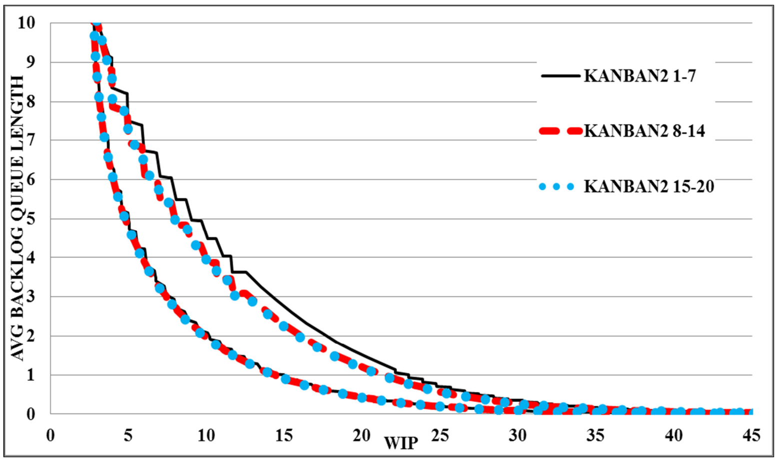


Figure 7 – Hybrid Kanban-CONWIP control strategy – Kanban 2 performance impact

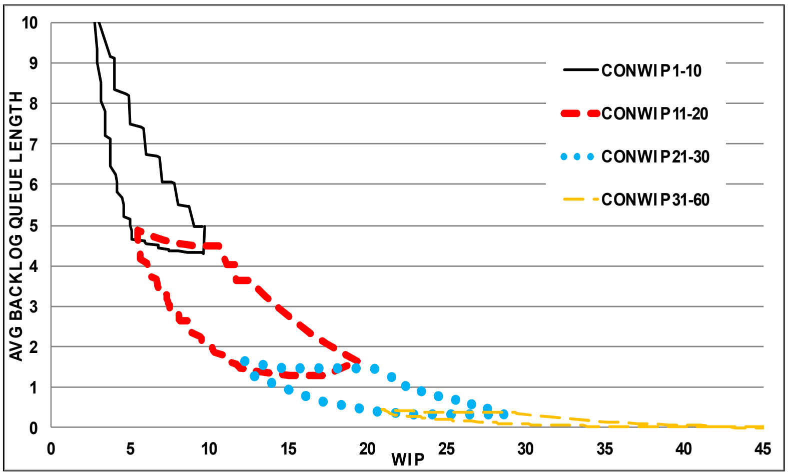


Figure 8 – Hybrid Kanban-CONWIP control strategy – CONWIP performance impact

Similar to the hybrid strategies, the importance of precise control of authorisation cards at Workstation 1 (Kanban1) is very significant for achieving high performance in terms of minimizing the WIP required to achieve a desired backorder level in the Kanban strategy (see Figure 9). The backorder level is most influenced by the combined settings for the Kanbans allocated to Workstations 2 & 3 (Kanban2 & Kanban3). As can be seen from Figures 10 & 11, if the decision maker requires low backorder levels then it is important to simultaneously set both Kanban2 & Kanban3 at high levels. Setting one lower could significantly degrade performance in terms of backorder level. A similar set of observations were drawn from investigating the Minimal Blocking strategy.

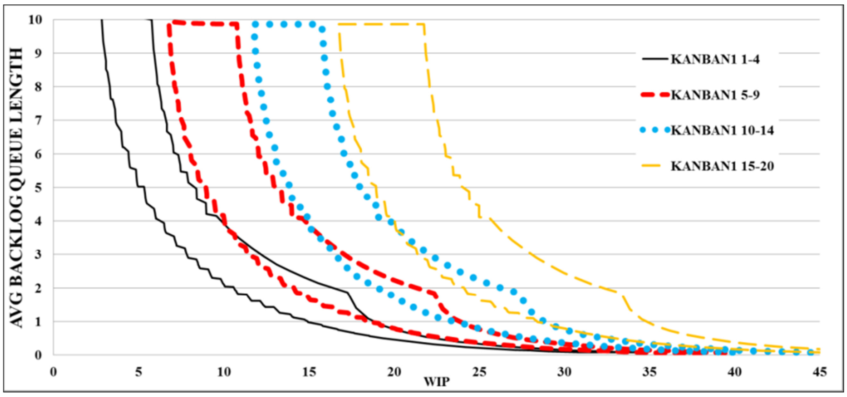


Figure 9 – Kanban control strategy – Kanban 1 performance impact

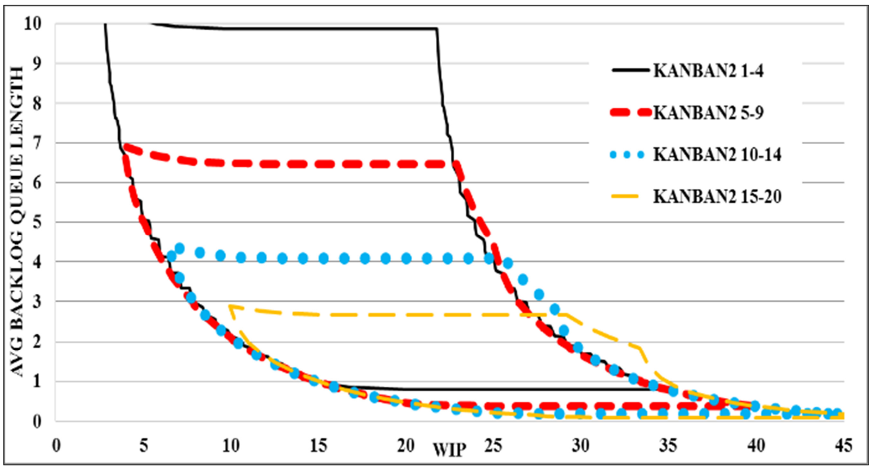


Figure 10 – Kanban control strategy – Kanban 2 performance impact

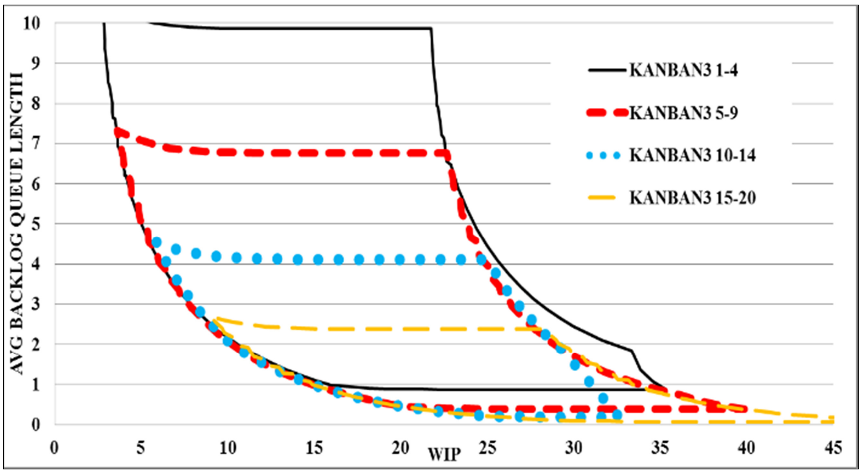


Figure 11 – Kanban control strategy – Kanban 3 performance impact

4. CONCLUSIONS AND FUTURE WORK

A number of observations of the influences of the control parameters (types of authorisation cards) have been drawn from examining the solutions in the experimental space. These observations may be useful for improving the efficiency of multi-objective genetic algorithms for investigating and optimising pull control strategies. For example, we are currently investigating how these insights might prove useful in the selection of Crossover and Mutation operations in a Multi-Objective Genetic Algorithm (MOGA) to minimise the computational effort required to derive the optimum (lower) Pareto front. For parameters that are have been demonstrated to be most influential in minimising WIP for a desired backlog level (Kanban1 in all cases examined here) it would be important to ensure that optimisation algorithm is able to create offspring with a high level of variance in this region of the chromosome, to avoid being trapped in a local optimum. Whereas, for parameters that have been shown to have the most influence of the backorder level (Kanban2 and Kanban3 in the Kanban control strategy and CONWIP cards in the Hybrid Kanban-CONWIP control strategies) it may be important to ensure that the optimisation algorithm generates offspring which are similar to each other in these sections of the chromosome. All remaining parameters could be maintained at predetermined levels, thus reducing the overall experimental search space. Further experimental work to characterise the impact of the bottleneck location and severity on the influences and importance of particular control parameters for each strategy is also required. This can be achieved by extending this analysis to longer lines.

5. ACKNOWLEDGMENTS

This work was sponsored by Irish Research Council, Irish Centre for Manufacturing Research (ICMR) and the Brazilian research agency CNPq (National Council for Scientific and Technological Development).

6. REFERENCES

[1] Sarker, B.R., Fitzsimmons J.A.: *The performance of push and pull systems: a simulation and comparative study*, The International Journal of Production Research, 27(10) (1989), 1715–1731.

[2] Spearman, M.L., Zazanis M.A.: *Push and pull production systems: issues and comparisons*, Oper.Res., 40 (3) (1992), 521–532.

[3] Bonvik, A.M., Couch C., Gershwin S.B.: *A comparison of production-line control mechanisms*, Int J Prod Res, 35(3) (1997), 789–804.

[4] Xanthopoulos, A., Koulouriotis D.: *Multi-objective optimization of production control mechanisms for multi-stage serial manufacturing-inventory systems*, The International Journal of Advanced Manufacturing Technology, 74(9–12) (2014), 1507–1519.

[5] Spearman, M.L., Woodruff D.L., Hopp W.J.: *CONWIP: a pull alternative to kanban*, The International Journal of Production Research, Vol.28 (5) (1990), 879–894.

[6] Andijani, A.:, *A multi-criterion approach for Kanban allocations*, Omega, 26(4) (1998), 483–493.

[7] Sharma, S., Agrawal N.:, *Selection of a pull production control policy under different demand situations for a manufacturing system by AHP-algorithm*, Comput.Oper.Res., 36(5) (2009), 1622–1632.

[8] Onyeocha, C.E., et al.: *A comparison of HK-CONWIP and BK-CONWIP control strategies in a multi-product manufacturing system*, Operations Research Perspectives, 2 (2015), 137–149.

[9] Smew, W., Young P., Geraghty, J.: S*upply chain analysis using simulation, Gaussian process modelling and optimisation*, International Journal of Simulation Modelling, 12(3) (2013), 178–189.

[10] Hou, T., Hu W.: *An integrated MOGA approach to determine the Pareto-optimal kanban number and size for a JIT system*, Expert Syst.Appl., 38(5) (2011), 5912–5918.

[11] Zitzler, E., et al.: *SPEA2: Improving the strength Pareto evolutionary algorithm*, 2001.

[12] Junior, M.L., Godinho Filho M., *Variations of the Kanban system: Literature review and classification*, Int J Prod Econ, 125(1) (2010), 13–21.

[13] Geraghty, J., Heavey C.: *A review and comparison of hybrid and pull-type production control strategies, OR Spectrum*, 27(2–3) (2005), 435–457.

SUSTAINABLE FIBRE FOR SUSTAINABLE FASHION SUPPLY CHAINS: WHERE THE JOURNEY TO SUSTAINABILITY BEGINS

Ewa WANKOWICZ[1]

[1]Sapienza University of Rome, Faculty of Economics, Department of Management
via del Castro Laurenziano, 9, Rome,
Italy

Abstract:

Adopting a sustainable business model is an essential element of gaining competitive advantage. Specifically, the management of fashion and textile supply chains characterized by geographical extension requires paying particular attention to environmental and social sustainability.Following an analysis of the literature on sustainable supply chains in the fashion and textile industries, this qualitatively based research examines – from a supply chain perspective – the sustainability initiatives implemented by a yarn and garment producer through a single case study. Subsequently, the classification of potential sustainability initiatives is presented. From this investigation, several good practices for sustainable fashion supply chains can be identified, providing a reference point for similar companies.

Keywords:

sustainable fashion supply chain, sustainable textiles, closed loop supply chain

1. INTRODUCTION

In 2010, cKinetics's report entitled March to Sustainability [1] postulated that the coming years would be focused on sustainability and the optimal use of natural resources to generate value in the textile supply chain. It seems that we have now reached that point. The fashion and textile industry is particularly sensitive to this issue due to the multiplicity of stakeholders involved in product creation. Furthermore, the global expansion of these sectors, and the consequent offshoring of several brands (to cite a few: Zara, H&M, Benetton etc.), have exposed the management of supply chains to many risks. The disruption of global supply chains might depend on their lack of sustainability compliance. The textile industry, whose main production area is in Asia, is one of the largest global industries after the oil industry; it is also one of the most polluting [2]. According to the European Commission, the impacts of textiles depend on the fibre from which the apparel is made and can be classified into energy use; greenhouse gas (GHG) emissions; eco toxicity from washing (water heating and detergents) and dying of textiles; resource depletion and GHG emissions from processing fossil fuels into synthetic fibres, e.g., polyester or nylon; water use; toxicity from fertiliser, pesticide and herbicide use; energy use and GHG emissions associated with fertiliser generation and irrigation systems related to production of fibre crops, e.g., cotton; and water use, toxicity, hazardous waste and effluent associated with the production stage, including pre-treatment chemicals, dyes and finishes. Realization of sustainable supply chains requires consideration of the social and economic aspects of sustainability as well. From a social perspective, workers in this sector are unskilled and underpaid. On the other hand, 70% of export earnings in developing countries derive from this sector (Allwood [3]. For many, achieving sustainability in the textile and fashion industry is full of contradictions. Particularly, the production of such a large amount of waste could constitute a significant impediment. However, as [4] mention, the market for sustainable fashion is growing ten times faster globally than the market for unsustainable fashion.

In addition, the survival of most existing supply chains will depend on the evolution of their current business models into new business models that carefully consider both environmental and social impacts. All actors contribute to shrinking the environmental footprint of textile products [5]. Because the textile and clothing supply chain is long and starts with fibre formation [6], the sustainability journey starts here as well, due to the considerable negative externalities that can be generated during this phase.

The pressing need to improve the way of doing business derives, to some extent, from legislative forces. [7] state that no industry improves sustainability in its supply chain without any external motivation. However, the voluntary actions undertaken by supply chain members can contribute to the achievement of a truly sustainable supply chain [8].

The research question is: how can textile industry members voluntarily contribute to the achievement of sustainable supply chains?

This paper is structured as follows: the next section presents the results of a literature review; next, the applied methodology is described; the fourth and fifth sections present findings and conclusive remarks, respectively.

2. SUSTAINABLE SUPPLY CHAIN MANAGEMENT IN THE TEXTILE INDUSTRY

In recent years, there has been growing attention to the sustainability of supply chains. Sustainability in fashion and textiles fosters ecological integrity, social equity and human flourishing through products, actions, relationships and practices [9].

This trend is the result of the dispersion of different phases of product creation around the globe. In this current economic scenario, the sustainability of a single business is not sufficient for the realization of the goals expressed in the Brundtland Report [10], as the economy is characterized by supply chain competition [11–18]. Table 1 presents some definitions of sustainable supply chain management applied to the fashion and textile industry.

Observing the current scenario, it seems that the fashion and textile industry is hardly achieving the goals of sustainable development. [28] propose a classification of practices for environmental sustainability in the textile industry, using six categories: product design, product materials, process, technology and processing materials, waste management, Strategic Environmental Assessment (SEA) and supply chain.

Sustainability in the fashion industry is relevant both to up-stream and down-stream supply chains. The first refers to practices of cleaner production, dye manufacturing and coloration processes [29–31]. The latter refers to use, reuse, recycling and disposal [32]. In particular, the sustainable fashion supply chain embraces the phases of eco-material preparation, sustainable manufacturing, green distribution, green retailing, and ethical consumption [33].

As a result of the abovementioned practices, a sustainable fashion product is made in an environmentally and socially friendly manner along the supply chain, which includes raw material production, manufacturing, distribution, and retailing. In this vision, focusing on supply chain management can assure the competitiveness of the company and allow the pursuit of environmental sustainability [34].

Table 1 – Sustainable fashion and textile supply chain definitions

SSCM – general overview	SSCM in textile and fashion supply chains
The sustainable management of a supply chain requires a broader vision and must highlight the economic, environmental and social aspects of business practice [19, p.264]	Management of sustainability along all fashion supply chains thus involves: resource production and extraction, fibre and yarn manufacturing, textile manufacturing, apparel assembly, packaging, transportation and distribution, consumer use, recycling and ultimate disposal [20].
The creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term. [21].	Social sustainability in the textile sector addresses: Work hours, fatigue [22] wages [23], skills development and training [24]; human rights [23], flexibility and security [23, 25], and health and working conditions [23, 26].
The management of supply chain operations, resources, information, and funds in order to maximize the supply chain profitability while at the same time minimizing the environmental impacts and maximizing the social well-being [27].	

One type of sustainable supply chain is the closed loop supply [35]. Undoubtedly, companies understand that striving for sustainability can enable the achievement of competitive advantage, but this requires them to rethink their business models, products, technologies, and processes [36, 37]. In particular, as [38] claim, the closed loop business model falls into the category of sustainable business models because closed loop management can ensure the sustainability of supply chains from the perspective of the triple bottom line (people, planet and profit[39].

Following [28] frameworks, fibres regenerated from waste constitute the element on which environmental sustainability can be based [40, 41]. In particular, regenerating fibres from waste permits companies to close the loop and is an essential element of supply chain sustainability, as closing the loop for many supply chains is becoming mandatory [42, p. 86].

Moreover, in the context of the rising prices of raw materials, finding new procurement sources has already become a requirement for long-term business sustainability [42]

The structure of the textile and fashion supply chain presented in Figure 1 shows that the sustainability of this industry is based on the involvement and collaboration of different actors [34].

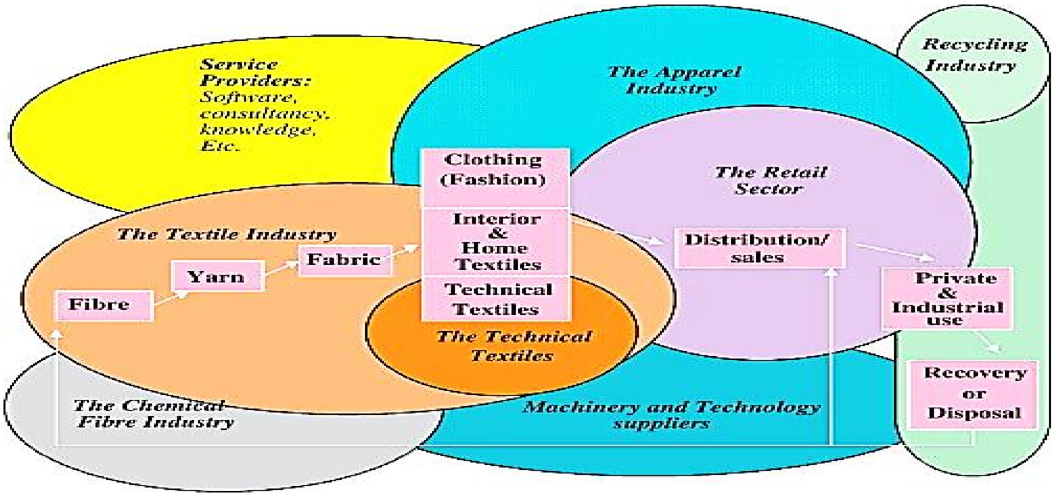


Figure 1 – The textile and fashion supply chain (adapted from EURATEX, 2004)

As global fibre production (mainly of cotton and polyester) has set a new global record of 86 million tons in 2013, reaching nearly 12 kg per capita [43] it is becoming essential to reuse and recycle.

3. METHODOLOGY

The main purpose of this paper is to understand the environmentally and socially responsible initiatives adopted by members of the textile industry. The research process was divided into two phases: a review of academic literature and reports published online and a case analysis. The case analysed here was selected from the Global Reporting Initiative database, which is considered by many researchers to be a valuable source of information as it is a global standard [44, 45, 46].
Selection was guided by the following criteria:

- The textile and apparel industry was selected as it was the object of the current study;
- Territory of Europe with a focus on Italy.

Because this study focuses on the sustainability of the supply chain, the abovementioned criteria were initially integrated with the selection of the latest report available on the GRI's website using the recently published GRI standard. After applying this criterion, only one company was identified.

Because of the voluntary nature of adherence to the GRI, the analysis of this company is of particular interest, as it may represent exceptional excellence within Italy.

However, analysing only one report seemed to the author to limit the scope of this paper. Therefore, this study presents the evolution of the environmentally and socially responsible initiatives conducted by the identified company, based on an analysis of all reports presented in the GRI database.

The company's website, and interviews obtained from internet sources, also constituted valid sources of data [The following interviews were analysed: https://www.youtube.com/watch?v=fR57-CSRJfM, CEO of Aquafil Giulio Bonazzi presentation at TED entitled *"The bright side of waste"*; https://www.youtube.com/watch?v=ZtK4k3oy5tA entitled *"Mezzo secolo di Aquafil"* https://www.youtube.com/watch?v=ZkqqkzRG_zo entitled *"Giulio Bonazzi parla della sostenibilità in Aquafil"*].

4. FINDINGS

4.1. Company profile

Aquafil Spa is privately owned; it was founded in 1969 and is headquartered in Italy (Arco, Trento). It is a leading global manufacturer of polyamide 6 fibre and polymer. It is present on three continents (Europe, Asia, America) and eight countries (Italy, Slovenia, Croatia, Germany, United Kingdom, USA (Georgia), Thailand and China). In 16 plants, the Group employs more than 2700 people. It produces two products that are used in two sectors' business units:

- Bulk continuous filament (BCF) yarn for carpets and textile flooring, and filaments used for textile flooring;
- Nylon textile filament (NTF) yarn for garments and clothing used in the apparel and sportswear industries;
- A third business unit dedicated to sustainability-related issues such as recycling, promoting the use of energy with a low environmental impact and/or from renewable sources, and the promulgation of sustainability and environmental culture [47].

All regenerated yarns by Aquafil are grouped under the ECONYL® brand. These yarns offer the same quality and performance as normal Nylon 6 but with incredible environmental benefits because they come from regenerated waste and are 100% endlessly regenerable.

Aquafil produces filaments (NTF) for clothing in the sectors of underwear, sportswear and beachwear, and polymers (EP) for sports equipment capable of ensuring the highest standard of care for the most extreme activities and climatic conditions [48].

There are six steps to closing the loop in Aquafil's production model: Recovery of waste, preparation of material, depolymerization, polymerization, transformation, and re-commercialization [49]. Due to space limitations the description of the phases of the production process realized at Aquafil is omitted. However, all detailed information about it can be found on the company's website and in its Sustainability Reports.

4.2. Sustainable initiatives undertaken by Aquafil

Table 2 represents the sustainability-oriented initiatives included in this report from 2007 to 2014 from a triple perspective, analysing both environmental and social efforts. The first set of efforts includes four elements: energy, emissions, wastes and water, whereas the second set addresses issues of corporate social responsibility. Environmental sustainability refers to *research into optimizing production processes while simultaneously meeting the commitments we have made to the customer and to protecting the environment* [50].

Table 2 – sustainability-oriented initiatives included in this report from 2007 to 2014

Year	2007	2008	2009	2010	2011	2012	2013	2014
Report's name	Sustainable report							
Sustainability is/is not	Sustainability is the crux of the dialogue between the Group and its customers, suppliers, employees and the local communities	Sustainability is not a result to be achieved; rather it is a way of thinking, a way of being, and a principle that must constantly guide us.					To be sustainable means to create values for stakeholders by using resources efficiently and respecting people and the environment without endangering the needs of future generation.	
GRI	GRI 3.0	GRI 3.0	GRI 3.0	GRI-Referenced	GRI - G3.1	GRI - G3.1	GRI - G3.1	GRI – G4
Environmental initiatives	a) 3,104,133 euro invested in reducing environmental impact, 44% for increasing energy efficiency, 23% for safety, 18% controlling emissions, 10% for the treatment of dangerous substances, 5% for managing water resources, 0.4% for reducing noise. b) Closing the loop: our scrap is converted into top quality yarn: Econyl 70 is made of 70% postindustrial scrap (30% virgin polymer).	a) Reduced use of natural resources, areas and spaces dedicated to landfills, reduced CO2 emissions by product unit by 50%. b) Replacing neon with low consumption systems c) Installing on-off light switches d) Increasing the efficiency of the internal energy production system d) registered The Eco Pledge brand	a) ECONYL® has attracted attention from the clothing industry; it contains a high percentage of recycled material. b) consolidated environmental balanced sheet; c) Development of closed loop cycle products that save natural resources and contribute to the regeneration of the environment. d)Energy efficiency improvement plan, e)Substitution of textile yarn reprocessing machinery motors with low energy consumption equivalents. f)Substitution of existing refrigeration machines with new low-consumption types. f)Heating of offices, canteen and changing rooms at Arco(It) with heat recovered from hot water. g)Elimination of 50 t/year of separated wastes through	a) Econyl plant uses secondary raw materials from post-industrial waste and post-consumer waste. b) Consolidating employee awareness towards recycling and waste separation.	a) Implementation of the Econyl ® Regeneration System that permits removing waste from the environment.	a)The Healthy Seas, a Journey from Waste to Wear'' project; b) EcoMeTex European Project (2012-2015)	a) Partnership with the Ellen MacArthur Foundation for Circular Economy 100, b) Adoption of Code of Conduct and an Organizational, Management and Control Model;	a) Renewal of the partnership with the Ellen MacArthur Foundation for circular Economy; b) Development of web tool for gathering information concerning the environment and for calculating performance indicators c)The purchase and installation of new equipment for pollution prevention; d) plan to extend ECONYL Qualified ® with the aim of

			the use of aluminium tubes.					encouraging all the suppliers who are part of the ECONYL ® supply chain to take steps toward improving their environmental indicators, thus helping to reduce the impact caused by the whole system.
Social initiatives	a) Multifaceted system of work shifts b) Professional development c) Safety and health in the workplace d) Promotion of recreational and sport activities e)Help with a smile project f) Scholarships for employees' distinguished children		a) Promotes the integration of the physically and mentally disabled and the socially disadvantaged into the community	a) Increased number of employees (despite negative macroeconomic situation), b)Schools and the industry work together initiative c) Cooperates with the ENAIP (Ente Acli Istruzione Professionale e) *We cook for you Event*	a)Project at Jiaxing,China ; b)Festival of Economics 2011, Trento(It), c)IFSC, Climbing World Championship 2011, Arco; d) Rollerski World Cup 2011, Oroslavje		a)Zero Infortuni initiative	a)The Nylla app was launched at the GreenTec Awards in May 2014 with the aim of raising children's awareness of the importance of recycling

4.3. Closing the loop

The company analysed here closes the loop through reintroduction of wastes (fishing networks, carpet fluff) into the cycle and production of new and infinitely reusable material to bring responsible products to life forever [49]. Sustainability issues in textiles require taking into account the influences emerging from outside the boundaries of the conventional textile industry, as well as going beyond companies and individual industries [51]. From this perspective, the organization's performance is [reported] in the wider context of sustainability [52]. Extracting raw materials from waste prevents the deposition of fishing nets into landfills, which could significantly damage the marine ecosystem [49]. Furthermore, the availability of recycled materials is an opportunity for clothing manufacturers to capitalize on the growing sensibility of consumers towards environmental issues [53] [Recently, Aquafil has collaborated with Levi Strauss & Co. for the creation of a denim collection that will be totally made from Econyl. As the

CEO of Aquafil stated "We envision a world where everyday items don't have to come at the expense of the environment. This new partnership is further proof that sustainable materials can be used to reinvigorate products that have been traditionally made. Levi's is redefining the denim industry." http://www.mycoolbin.com/2016/04/09/levis-teams-with-aquafil-for-sustainable-jeans-line/] Producing 10,000 tons of ECONYL® saves 162,000 GJ of energy, eliminates 11,000 tons of waste, and saves 70,000 barrels of oil [48]. Econyl® products are waste positive, meaning that *the amount of waste removed from the environment and used for the production of the same is greater than the amount of waste resulting from the production process* [48].

5. CONCLUDING REMARKS

Sustainability, seen as *the new challenge of the future, [which] will enable every company to grow and develop* [50] also plays an important role in managing the fashion and textile supply chain both upstream and downstream. For this reason, every negative and positive action affecting both environmental and human health should be evaluated from a supply chain perspective because *The sustainability of an individual organization may, or may not, be compatible with the sustainability of society as a whole, which is attained by addressing social, economic and environmental aspects in an integrated manner* [54]. However, assuring environmental protection within supply chains requires collaboration between suppliers and customers and also creates an opportunity to develop new commercial and business relationships. Furthermore, these relationships are essential for the journey towards sustainability, the creation of a circular economy, and the success of sustainable supply chains [53].

This study aimed to provide a preliminary analysis of one company's interpretation of sustainability in the textile and clothing industry. Numerous opportunities for future research arise from this study. We need a deeper understanding of the motivations that guide companies operating in this sector to manage their supply chains sustainably; an analysis of an entire company's supply chain to know how (and if) its members are currently adapting to the postulates of sustainable development; and a better understanding of how cross-sector collaboration can foster the creation of sustainable textile and clothing supply chains.

6. REFERENCES

[1] Report March to sustainability, www.ckinetics.com/MarchToSustainability2010/, 15-01-2016

[2] Martin M.: *Creating Sustainable Apparel Value Chains: A Primer on Industry Transformation Impact Economy*, 2013, www.impacteconomy.com/en/primer2.php, 15-12-2015

[3] Allwood J.M., Laursen SE, Russell SN, de Rodríguez CM, Bocken NMP.: *An approach to scenario analysis of the sustainability of an industrial sector applied to clothing and textiles in the UK. A brief introduction to the clothing and textiles sector*, Journal of Cleaner Production 16(12)(2007), 1234-1246

[4] Kruse,E., Storm Rasmussen, V.: *Sustainable fashion is sustainable growth*, http://www.b.dk/kommentarer/baeredygtig-mode-er-baeredygtig-vaekst, 15-01-2016

[5] Retail Forum for Sustainability, Sustainability of textiles, 11 (2013), 1-7, 14-02-2016

[6] Muthu S.S.: *Assessing the environmental impact of Textile and the clothing supply chain*, Woodhead Publishing, Cambridge, 2014

[7] Pagell, M., Shevchenko, A.: *Why research in sustainable supply chain management should have no future*, Journal of Supply Chain Management, 50(1)2014, 44–55.

[8] Pagell M., Wu Z.: *Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars*, Journal of Supply Chain Management, (45)(2)(2009), 37–56

[9] Fletcher K., Tham M.: *Routledge Handbook of Sustainability and Fashion*, 1 Ed., New York, 2014

[10] WCED, Our Common Future, Oxford University Press, Oxford., 1987

[11] Antai, I.: *A theory of the competing supply chain: alternatives for development*, International Business Research, (4)(1)(2011)74–85

[12] Ashby, A., Leat, M., Hudson-Smith, M.: *Making connections: a review of supply chain management and sustainability literature*, Supply Chain Management, (17)(5)(2012), 497–516

[13] Christopher, M. *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Services*, Pitman Publishing, London, 1992

[14] Christopher M.: *Logistics and Supply Chain Management*, Pearson Education, 2005

[15] Christopher, M.: *The agile supply chain: competing in volatile markets*, Industrial Marketing Management, (29)(1)(2000), 37–44.

[16] Cozzolino, A.: *Operatori Logistici. Contesto Evolutivo, Assetti Competitivi e Criticità Emergenti Nella Supply Chain*, Cedam, Padova, 2009.

[17] Liu, C.H., Chen, M.C., Tu, Y.H., Wang, C.C.: *Constructing a sustainable service business model*, International Journal of Physical Distribution and Logistics Management, (44)(1–2)(2014), 80–97.

[18] Massaroni, E., Cozzolino, A.: *Modelli Della Produzione Industriale*, Cedam, Padova, 2012

[19] Svensson G.: *Aspects of sustainable supply chain management (SSCM): conceptual framework and empirical example*, Supply Chain Management, (12)(4)(2007), 262–266.

[20] Kozlowski A., Searcy C., Bardecki M.: *Corporate sustainability reporting in the apparel industry: An analysis of indicators disclosed*, International Journal of Productivity and Performance Management, (64) (3)(2015), 377–397

[21] Ahi, P. Searcy, C.: *A comparative literature analysis of definitions for green and sustainable supply chain management*, Journal of Cleaner Production, (52)(1)(2013), 329–341

[22] Metzner, R.J., Fischer, F.M.: *Fatigue and workability in Brazilian textile companies in different corporate social responsibility score groups*, International Journal of Industrial Ergonomics, 40(2010), 289–294

[23] Barendt, R., Musiolek B.: Workers' Voices: *The situation of women in the Eastern European and Turkish garment industries*, Clean Clothes Campaign & Evangelische Akademie Meißen, https://www.cleanclothes.org/resources/national-cccs/05-workers-voices.pdf (2005) 14-04-2016

[24] Eurofound – European Foundation for the Improvement of Living – and Working Conditions- (2002) Quality of work and employment in Europe. Found. paper No. 0212. http://www.eurofound.europa.eu/pubdocs/2002/12/en/1/ef0212en.pdf, 17-02-2016

[25] Koçer, R. G., Fransen, L.: *Codes of conduct and the promise of a change of climate in worker organization*., European Journal of Industrial Relations, (15)(2009), 237–251

[26] Michalski, R.: *Computer-aided subjective assessment of factors disturbing the occupational human performance*, Occupational Ergonomics, 7(2006), 27–42

[27] Hassini E., Surti C., Searcy C.: *A literature review and a case study of sustainable supply chains with a focus on metrics*, International Journal of Production Economics (140)(1)(2012), 69-82

[28] Resta B., Dotti S., Pinto R., Bandinelli R., Rinaldi R., Ciarapica F.E.: *Practices for Environmental Sustainability in the Textile, Clothing and Leather Sectors: The Italian Case*, International Journal of Opersions and Quantitative Management, 20(3)(2014), 193-225

[29] Dawson T.: *Progress towards a greener textile industry*, Coloration Technology, (128)(1)(2012), 1–8,

[30] Moore, S.B., Ausley, L.W.: Systems thinking and green chemistry in the textile industry: concepts, technologies and benefits, Journal of Cleaner Production, (12)(2004), 585–601.

[31] SØndergard, B., Hansen, O.E., Holm, J.: *Ecological modernisation and institutional transformations in the Danish textile industry*, Journal of Cleaner Production, (12)(2004), 337–352.

[32] Clancy G., Froling M., Peters G.: *Ecolabels as drivers of clothing design*, Journal of Cleaner Production, 99(2015), 345–353.

[33] Shen, B.; Zheng, J.; Chow, P.; Chow, K.: *Perception of fashion sustainability in online community*, Journal of The Textile Institute, (105)(2014), 971–979

[34] Coniato, F., Caridi, M., Crippa, L., Moretto, A.: *Environmental sustainability in fashion supply chains: an exploratory case based research*, International Journal of Production Economics, (135)(2)(2012), 659–670.

[35] Govindan, K., Soleimani, H. and Kannan, D.: *Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future*, European Journal of Operational Research 240(3)(2015), 603–626

[36] Sujith N., Paulose H.: *Emergence of green business models: the case of algae biofuel for aviation*, Energy Policy, (65)(2014), 175-184.

[37] Massaroni E., Cozzolino A., Wankowicz E.: *Sustainable supply chain management needs sustainable packaging. An exploratory study*, Proceedings of SinergieConference, Cassino, November 2013

[38] Wells P., Seitz M.: *Business models and closed-loop supply chains: a typology*, Supply Chain Management-International Journal, (10) (3/4)(2005), 249–251

[39] Elkington J.: *Cannibals with forks: The Triple Bottom Line of 21st Century Business*, Capstone Publishing LTD, Oxford, 1998,

[40] Poole, A.J., Church, J.S., Huson, M.G.: *Environmentally sustainable fibers from regenerated protein*, Biomacromolecules, (10)(1)(2008), 1–8.

[41] Shen, L., Worrell, E., Patel, M.K.: *Open-loop recycling: A LCA case study of PET bottle-to-fibre recycling*, Resources, conservation and recycling, (55)(1) (2010b), 34–52

[42] Bouzon, M., Govindan, K.: *Reverse Logistics as a Sustainable Supply Chain Practice for the Fashion Industry: An Analysis of Drivers and the Brazilian Case in Sustainable Fashion Supply Chain Management*. Choi, T-M. & Cheng, T. C. E. (eds.). Springer, 2015, 85–104.

[43] Deloitte (2013), *Fashioning Sustainability*, Deloitte, Copenhagen.

[44] Marimon F., Alonso-Almeida MM., Rodriguez MP., Cortez A.: *The worldwide diffusion of the global reporting initiative: what is the point?*, Journal of Cleaner Production, 33(2012), 132–144

[45] Roca L.C., Searcy C.: *An analysis of indicators disclosed in corporate sustainability reports*, Journal of cleaner production, 20(2012), 103–118

[46] Legendre S., Coderre, F.: *Determinants of GRI G3 Application Levels: The Case of the Fortune Global 500*, Corporate Social Responsibility & Environmental Management, (20)(2013)(3), 182–192

[47] Aquafil Sustainability Report 2010, http://database.globalreporting.org/reports/view/11580, 15-01-2016

[48] Aquafil Sustainability Report, 2012, http://database.globalreporting.org/reports/view/19936, 15-01-2016

[49] Aquafil Sustainability Report, 2013, http://database.globalreporting.org/reports/view/23210, 15-02-2016

[50] Aquafil Sustainability Report, 2007, http://database.globalreporting.org/reports/view/11582, 15-01-2016

[51] Gardetti M.A., Torres A.L. *Sustainability in Fashion and Textiles. Values, Design, production and consumption*, Greenleaf Publishing, 2013

[52] GRI, Implementation Manual, 2013, www.globalreportinginitiative.org

[53] Aquafil Sustainability Report, 2011, http://database.globalreporting.org/reports/view/11579

[54] GRI ISO, http://www.iso.org/iso/iso-gri-26000_2014-01-28.pdf

MULTI-CRITERIA WAREHOUSES LOCATION PROBLEM IN THE LOGISTICS NETWORK

Mariusz WASIAK[1], Ilona JACYNA-GOŁDA[2], Mariusz IZDEBSKI[1]

[1]Warsaw University of Technology, Faculty of Transport
Koszykowa Street 75, Warsaw,
Poland
[2]Warsaw University of Technology, Institute of Organisation of Production Systems
Narbutta Street 85, Warsaw,
Poland

Abstract:

This paper presents multi-criteria warehouses location problem in the logistics network. In order to solve this problem the location model of warehouse facilities within logistic network for manufacturing sector was developed. The limitations and optimization criteria of the model were determined. Optimization criteria refer to transport and storage costs, the total length of routes for vehicles carrying out the supplies, the land area for further expansion, the distance of warehouses from main transport routes. The final location of warehouse facilities was obtained using a point multi-criteria method.

Keywords:

multi-criteria warehouses location problem, a point multi-criteria method, logistic network

1. INTRODUCTION

The problem of warehouse situation is an issue that is generally known and widely discussed in the context of decision-making problems forming the logistical network of various types of enterprises. Depending on the complexity and structure of the network, the problem is being modified and acquires diverse forms. The classical issue of warehouse location is commonly defined in available literature as the capacitated warehouse location problem CWLP[1–3]. The structure of the logistic network consists of warehouse facilities and customers. The main objective is to find such a location of warehouse facilities that the costs arising from forwarding of a specific volume of goods to the customers are as low as possible. The transport cost depends on the volume of goods carried between warehouses and customers and also on the distance between them, and hence it is also necessary to set out volumes of carried goods. Limitations, on the other hand, arise from satisfying the needs of all customers and the capacitive limit for the dispatch of goods from the given warehouse facility. If no capacity limitation is imposed, we are faced with an uncapacitated warehouse location problem [4].

The basic stage in the configuration of logistic networks is the selection of locations of spot elements [5]. The logistical network is a set of elements (items): suppliers, manufacturers, wholesalers and recipients bound by diverse relations connected with the flow of materials. Depending on the number of intermediates on the transport route, the network structure may be single-level [3] or multi-level [6–10] which is called a hierarchical one. One of the characteristic features of the multi-level network is that materials have to flow from suppliers via subsequent levels to recipients. In the multi-level network there are intermediaries, such as various types of warehouses, reloading terminals and logistic centres.

The problem of locating warehouse facilities is also studied in the context of planning the routes that vehicles have to cover. In this case it is defined in literature as warehouse location-routing problem [11,12]. The objective is to determine the location of warehouse facilities and goods delivery routes from warehouses to each customer, so that the cost arising from transport of a defined volume of goods to the customers is the lowest possible. This takes into consideration a situation in which the route of each vehicle contains a few unloading points (customers).

Furthermore, the problem of warehouse situation may be reviewed from two basic viewpoints. The first one is selecting the place where a new warehouse is to be erected [1,3,9] with respect to various viewpoints and the designed margin conditions. Basically in such a case potential locations for the construction of a new warehouse are indicated. The second aspect consists in the selection of warehouse locations from the already existing facilities. This implies a need for reconfiguration of the logistic network for the given sector, etc. [5,13].

In many cases, due to the multi-aspect nature of location problems, it is necessary to take into account optimising criteria that determine the choice of the best location solution. As regards the construction of a new warehouse, of particular importance are among others costs for land purchase for needs of construction works or the available land lot area. On the other hand, as regards restructuring of the logistic network, the selection of warehouses depends primarily on their distance from the remaining elements of the network, such as suppliers or recipients.

The warehouse location problem in the logistics network is multi-criteria optimization problem that depends on quantitative and qualitative criteria. In this issue the following criteria may be distinguished [9,14–19]:

- Costs: labour costs, transportation costs, storage costs, taxes. Labour costs change with respect to the life conditions at alternative locations. Transportation cost depends on the size of the cargo transported between facilities of the logistics network, distances between the warehouse and facilities within the network. Storage costs and taxes are different according to the regions.
- Labour characteristics: skilled labour and availability of labour force. This criterion determines the state of qualified labour at a given location. Skilled labour defines the personnel with appropriate qualities to perform work. The skilled labour and availability of labour force may be different according to the regions.
- Infrastructure: existence of modes of transportation, quality and reliability of modes of transportation. Existence of modes is understood as the availability of different transportation types in the given location e.g. railway. Quality and reliability of modes of transportation refers to timely deliveries.
- Market: proximity to customers, suppliers or producers. These factors in large degree influence on the transportation costs.
- Macro environment: policies of government e.g. tax exemptions.

The presented criteria emphasise the complexity of the problem arising from location of storage facilities and in a certain way determine the application of the multi-criteria decision-making assistance in selection of the optimum solution [9,15–19]. Multi-criteria decision assistance [20,21] is meant to provide the decision-maker with tools that allow solution of complex problems allowing for numerous viewpoints, as a rule quite contradictory.

The ultimate location of warehouse facilities arises from an assessment of diverse design variants executed using methods of multi-criteria assessment, such as for example the MAJA method [22] or the spot method [9,23]. Figure 1 presents a diagram of the decision-making process in warehouses selection.

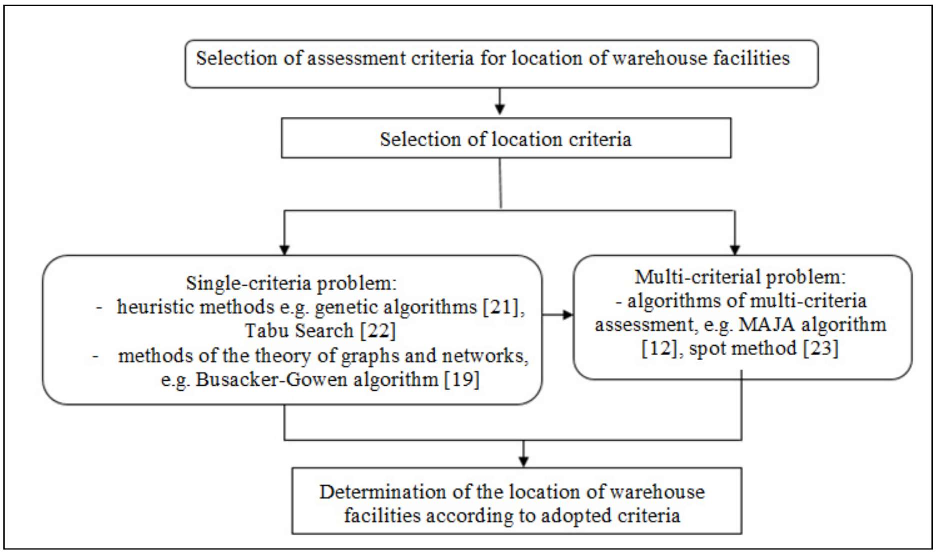


Figure 1 – Procedure for determination of warehouse facilities location

The article presents a location model for warehouse facilities for needs of handling a manufacturing plant taking into account four partial criteria. The model also takes into account the raw material flow in the logistic network on each working day of a manufacturing plant. It may also serve as a basis for the development of supply and receipt schedule of production raw materials, and in addition emphasises the practical aspect of the location problem subject to analysis. The final selection of warehouse location was done with the use of the spot method.

2. LOCATION MODEL OF WAREHOUSE FACILITIES WITHIN LOGISTIC NETWORK FOR MANUFACTURING SECTOR

2.1. General assumptions

The analysis comprises a logistic network of manufacturing plants. The network structure comprises the following: suppliers, warehouses and manufacturing plants. The suppliers may deliver raw materials directly or indirectly via warehouse facilities to manufacturing plants. The model assumes that the demand of recipients (manufacturing plants) is lower or equal to manufacturing capacity of the suppliers, and hence in each case the producers' demand would be met. Elements of structure in the analysed logistic network were presented on Figure 2.

The main objective is to determine the location of warehouse facilities from among those that are available in order to assure the best value of the adopted criterion function with concurrent satisfaction of needs of the recipients. The considered partial criteria comprised the minimum transport cost and raw materials passage through the warehouse, the minimum distance of supply execution to manufacturers, the maximum land area for further development, the minimum distance from the main transport routes. Data of the analysed case concern served manufacturing plants, potential location points of warehouse facilities and transport links used for the implementation of supplies.

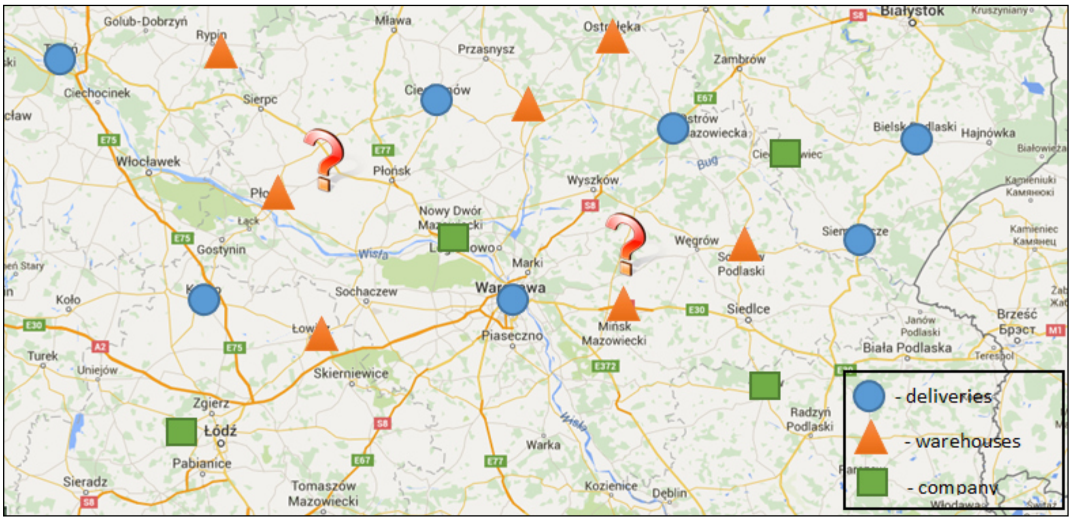


Figure 2 – Elements in the logistic network of manufacturing plants

The following definitions have been formulated for the needs of establishing a location model:
$V = \{v: v = 1, 2, ..., v, ..., V\}$ – set of numbers of spot elements of the logistical network: suppliers, warehouses, manufacturing plants,
$T = \{t: t = 1, 2, ..., t', ..., T\}$ – set of numbers of working days,
$DS = \{v: \alpha(v) = 0 \text{ for } v \in V\}$ – set of numbers of suppliers,
$MS = \{v: \alpha(v) = 1 \text{ for } v \in V\}$ – set of numbers of warehouses,
$P = \{v: \alpha(v) = 2 \text{ for } v \in V\}$ – set of numbers of manufacturing plants,
$D1 = [d1(v,v'): d1(v,v') \in R^+, v \in DS, v' \in MS]$ – distance matrices in relations: suppliers–warehouses,
$D2 = [d2(v,v'): d2(v,v') \in R^+, v \in DS, v' \in P]$ – distance matrices in relations: suppliers–enterprises,
$D3 = [d1(v,v'): d3(v,v') \in R^+, v \in MS, v' \in P]$ – distance matrices in relations: warehouses–enterprises,
$Q1 = [q1(v)]$ – vector of the volume of deliveries from suppliers,
$Q2 = [q2(v,t)]$ – matrix of the demand volume of enterprises on particular working days in pallet loading units,
$Q3 = [q3(v)]$ – vector of total demand of enterprises in pallet loading units,
$POJ = [poj(v)]$ – vector of warehouse capacity,
$K = [k(v)]$ – vector of passage costs of a load unit through the warehouse facilities,
$N = [n(v,v')]$ – matrix of the average pallet load units carried with one vehicle between particular points of the logistic network,
$LP = [lp(v)]$ – vector of additional land area for further development of warehouses in their particular locations,
$LK = [lk(v)]$ – vector of the distance of warehouses from the transport route,
$C = [c(v,v')]$ – matrix of transport costs of load unit per distance unit between particular facilities of the network.

2.2. Decision variables of model

Two types of decision–based variables were introduced, variables that define the volumes of cargo forwarding between particular facilities expressed in pallet cargo units and a binary variable that defines the selection of location for warehouse facilities. The variable that defines the volume of material stream flow between particular facilities serves the needs of determining the location of facilities from the viewpoint of minimum transport and storage costs and from the viewpoint of minimising the total length of supply routes. On the other hand, the binary variable was taken into account to delimit the location of warehouses with view to the maximum land area designated for further development and the minimum distance from main transport routes.

The first type of variable formulated as matrix **X**1 (relation: suppliers – warehouses), **X**2 (relation: suppliers – manufacturing plants), **X**3 (relation: warehouses – manufacturing plants) on the interpretation of the volume of raw materials carried between network points on a given working day acquires the following form:

$$X1 = \left\lfloor x1(v,v',t) : x1(v,v',t) \in R^{+} \cup \{0\}, v \in DS, v' \in MS, t \in T \right\rfloor \tag{1}$$

$$X2 = \left\lfloor x2(v,v',t) : x2(v,v',t) \in R^{+} \cup \{0\}, v \in DS, v' \in P, t \in T \right\rfloor \tag{2}$$

$$X3 = \left\lfloor x3(v,v',t) : x3(v,v',t) \in R^{+} \cup \{0\}, v \in MS, v' \in P, t \in T \right\rfloor \tag{3}$$

The second type of variable assumes the following form:

$$Y = [y(v) : y(v) \in \{0,1\}, v \in MS] \tag{4}$$

Variable $y(v)$ assumes the value of 1 when the given warehouse is comprised by the logistic network of manufacturing plants and 0 if it is not.

2.3. Border conditions of location model

When formulating decision-making problems one of the main stages is to determine the system of limitations of the so-called border conditions. This is indispensable to determine the set of admissible solutions. To be able to achieve the solution, the set of admissible solutions has to be must at least contain a single element.

The analysed case has to take into account limitations arising from expectations of enterprises, their work pace and implementation of the manufacturing process, as well as limitations resulting from possibilities of the suppliers and also organisational and legal conditions of delivery implementation.

Main limitations of the model have been defined below.

1. Warehouses tend to have a limited capacity, and so the total of cargo volume supplied to each warehouse may not exceed its admissible capacity. Usage of the warehouse capacity depends on the volume of raw material delivered to the warehouse on the present working day and on the amount of raw material dispatched on the same day from the warehouse (first two elements of formula (5) and on the warehouse state on the preceding working days (element 3 and 4 from formula (5).
2. Maintaining the raw material flow stream through the warehouse, formula (6). Volume of raw material coming out from the given warehouse in a given working day may not exceed the current state of the warehouse on that day.

3. The entire cargo has to be collected from the supplier on a given working day, formula (7). The suppliers do not store the raw material. The limitation eliminates a situation in which a manufacturing plant does not use warehouses and picks up raw materials from the suppliers.
4. The demand of manufacturing plants in a given working day has to be met, formula (8).
5. Total demand of manufacturing plants has to be met, formula (9).
6. Limitations connected with the flow of cargo, i.e. the elimination of incorrect flows, non-negativity of flows, maintaining the flow volumes, excluding cyclical flows.
7. Keeping supply deadline in accordance with the adopted schedule.

Sample limitations in the mathematical form have been formulated in the following way:

$$v' \in MS, t \in T$$

$$\sum_{v \in DS} x1(v,v',t) - \sum_{v \in P} x3(v',v,t) + \sum_{t'=1}^{t-1} \sum_{v \in DS} x1(v,v',t') - \sum_{t'=1}^{t-1} \sum_{v \in P} x3(v',v,t') \le poj(v') \quad (5)$$

$$v' \in MS, t \in T \sum_{v \in DS} x1(v,v',t) + \sum_{t'=1}^{t-1} \sum_{v \in DS} x1(v,v',t') - \sum_{t'=1}^{t-1} \sum_{v \in P} x3(v',v,t') \ge \sum_{v \in P} x3(v',v,t) \quad (6)$$

$$v \in DS, t \in T \sum_{v' \in MS} x1(v,v',t) + \sum_{v' \in P} x2(v,v',t) - q1(v) = 0 \quad (7)$$

$$v' \in P, t \in T \sum_{v \in DS} x2(v,v',t) + \sum_{v \in MS} x3(v,v',t) - q1(v) = q2(v',t) \quad (8)$$

$$v' \in P \sum_{t \in T} \sum_{v \in DS} x2(v,v',t) + \sum_{t \in T} \sum_{v \in MS} x3(v,v',t) = q3(v') \quad (9)$$

2.4. Optimisation criteria

As has already been mentioned, selection of locations for warehouse facilities must take into account several aspects. The optimum configuration of the logistic network for needs of handling manufacturing plants is one that assures maximum benefits from the viewpoint of manufacturing plants (recipients) and minimum costs from the viewpoint of service providers. Consequently the defined configuration has to ensure obtaining services at an attractive price maintaining concurrently the appropriate quality of those services. The executed considerations suggest that seeking the best configuration of the logistic network should be based on several criteria – comprising different points of view as to the quality of solution – taken into account as partial assessment criteria. The vital partial assessment criteria, which should be taken into consideration for the assessment of admissible network configurations comprised the following:

1. minimum transport and storage costs,
2. minimising of the total length of routes for vehicles carrying out the supplies,
3. maximising the land area for further expansion,
4. minimising the distance of warehouses from main transport routes.

The formal partial criteria functions have been determined as follows:

1. minimum transport and storage costs:

$$F2(X1,X2,X3) = \\ = \sum_{v \in DS} \sum_{v' \in MS} \sum_{t \in T} x1(v,v',t) \cdot d1(v,v') \cdot c(v,v') + \sum_{v \in DS} \sum_{v' \in P} \sum_{t \in T} x2(v,v',t) \cdot d2(v,v') \cdot c(v,v') + \\ + \sum_{v \in MS} \sum_{v' \in P} \sum_{t \in T} x3(v,v',t) \cdot d3(v,v') \cdot c(v,v') + \sum_{v \in DS} \sum_{v' \in MS} \sum_{t \in T} x1(v,v',t) \cdot k(v') \to \min \quad (10)$$

2. minimising of the total length of routes for vehicles carrying out the supplies (the minimum routes entails a briefer supply implementation time; to allow the determination of the route length a calculation was made of the number of travels between particular points of the network):

$$F2(X1,X2,X3)=$$
$$=\sum_{v\in DS}\sum_{v'\in MS}\sum_{t\in T}\left\lceil\frac{x1(v,v',t)}{n(v,v')}\right\rceil\cdot d1(v,v')+\sum_{v\in DS}\sum_{v'\in P}\sum_{t\in T}\left\lceil\frac{x2(v,v',t)}{n(v,v')}\right\rceil\cdot d2(v,v')+$$
$$+\sum_{v\in MS}\sum_{v'\in P}\sum_{t\in T}\left\lceil\frac{x3(v,v',t)}{n(v,v')}\right\rceil\cdot d3(v,v')\rightarrow \min \tag{11}$$

3. maximising the land area for further expansion:

$$F3(Y)=\sum_{v\in MS}y(v)\cdot lp(v)\rightarrow \max \tag{12}$$

4. minimising the distance of warehouses from main transport routes:

$$F4(Y)=\sum_{v\in MS}y(v)\cdot lk(v)\rightarrow \min \tag{13}$$

The determination of partial values of criteria is made for admissible solutions obtained taking into consideration limitations specified in item 2.3.

It is expected that the optimum configuration of the logistic network should allow achieving maximum benefits both to enterprises that make use of the planned network, as the handling companies. Consequently the objective is to find a compromise solution, i.e. optimum in the Pareto sense, and namely one for which values of all considered assessment criteria are the most advantageous (but not necessarily extreme ones). As is generally known, the implementation of such an approach is only possible thanks to multi-criteria optimising. The method of multi-criteria configuration assessment of the logistic network taking into account in the paper allows the determination of its best configuration pursuant to adopted criteria and providing for the decision-maker's preferences.

3. MULTI-CRITERIA ASSESSMENT OF WAREHOUSE LOCATION

The diversity of optimisation criteria imposes the necessity of adopting the multi-criteria method to allow the selection of a warehouse location variant and taking into account weights for particular criteria. The final location of warehouse facilities may be obtained with the use of a point multi-criteria method. The algorithm of the point method along with the mathematical structure is available in [10, 19]. Particular stages of calculations carried out by the adopted algorithm of multi-criterial assessment may be presented in the following way (Figure 3):

a. Introduction of input data, based on which locations of warehouse facilities are set out.
b. Selection of an algorithm that sets out the admissible location variants for warehouse facilities. The determination of admissible locations of warehouse facilities was executed with the LogMND [9] programme based on the Busacker-Gowen algorithm.
c. Determination of admissible location variants for warehouse facilities. In this stage of calculations a set of numbers is delimited for variants of preferred locations for warehouse facilities taking into consideration partial assessment criteria, which have been defined as:

$$L=\{l:l=1,2,...,L\} \tag{14}$$

d. Determination of matrices of assessments of warehouse location variants. For the admissible variants of warehouse locations a determination is made of partial values of assessment criteria, which in the subsequent stage of calculations are subjected to standardisation. The set of partial criteria has been defined as follows:

$$F = \{f : f = 1,2,..., F\} \tag{15}$$

where:
$f = 1$ – criterion of transport and warehousing costs [PLN], formula (10),
$f = 2$ – criterion of total length of routes over which goods are delivered [km], formula (11),
$f = 3$ – criterion of land designated for further development [m^2], formula (12),
$f = 4$ – criterion of warehouse distance from main transport routes [km], formula (13).

The matrix of location assessments has been defined as follows:

$$X = \lfloor x(f,l) : x(f,l) \in R^+ \cup \{0\}, f \in F, l \in L \rfloor \tag{16}$$

Standardisation of assessment values of preferred warehouse locations depends on the nature of adopted sub-criteria. As regards the search for the maximum values of criteria, the standardised assessment is determined according to formula (17), while as regards minimising of the criterion based on the following formula (18):

$$w(f,l) = \frac{x(f,l)}{\max_{l' \in L}\{x(f,l')\}} \cdot 10 \tag{17}$$

$$w(f,l) = \frac{\min_{l' \in L}\{x(f,l')\}}{x(f,l)} \cdot 10 \tag{18}$$

e. The determination of relative partial values of assessment criteria $c(f)$. It was adopted that the relative weight of the given assessment is a figure within the range of <0, 100%>, with the total of relative importance of all the considered assessment criteria equals to 100%.

f. Determination of assessment indices for each of the considered location variants $W(l)$ according to formula (19):

$$\forall l \in L W(l) = \sum_{f \in F} c(f) \cdot w(f,l) \ \forall \mathrm{l} \in \mathrm{L} \tag{19}$$

The warehouse location variant with the highest value of the assessment index constitutes the most advantageous solution.

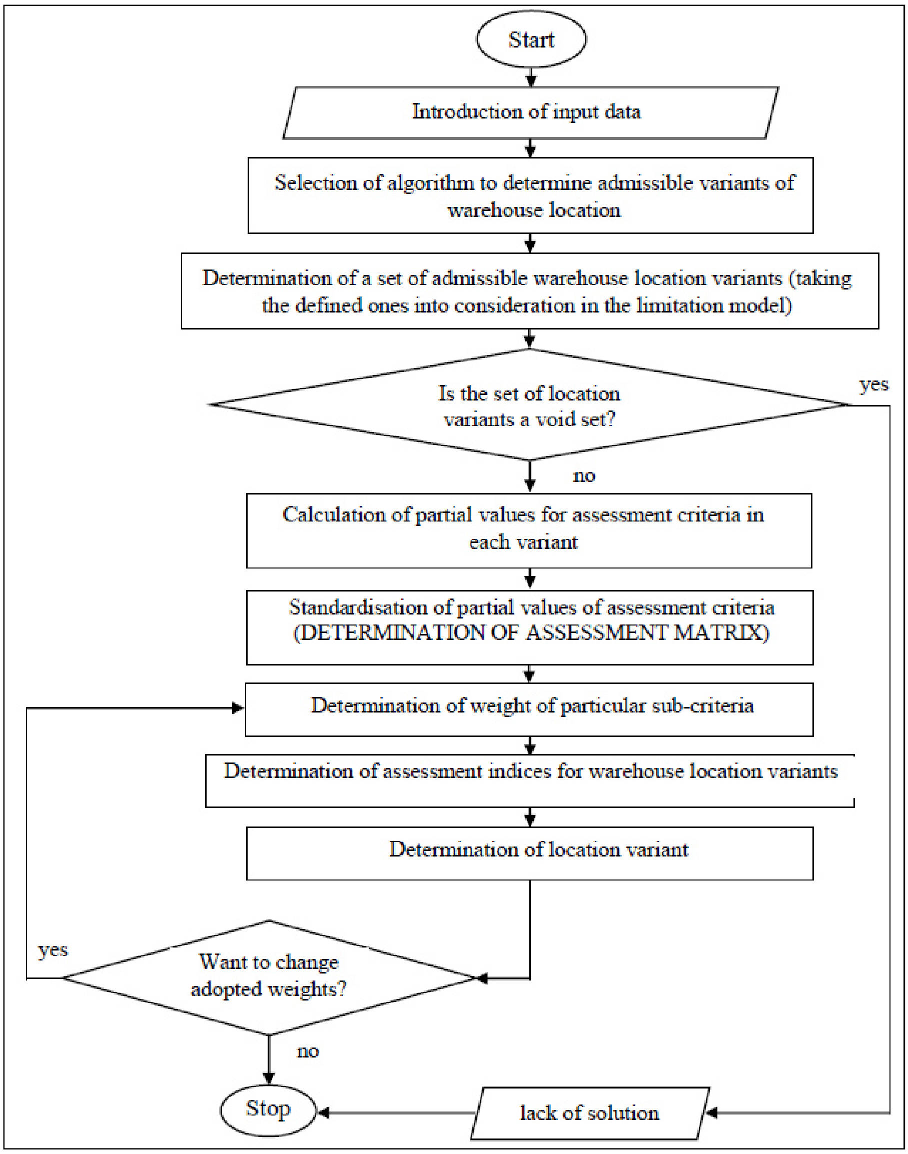


Figure 3 – Multi-criteria assisting of decisions related to warehouse locations

4. PRACTICAL EXAMPLE OF LOCATION SELECTION OF WAREHOUSE FACILITIES IN LOGISTIC NETWORK

The analysed logistic network consisted of suppliers, warehouse facilities and manufacturing plants. Three potential locations of warehouse facilities have been defined – *L*1, *L*2, *L*3 (Figure 4), with the location of two of them in the logistic network being an optional one. This means that the logistic network may consist in one, two or three warehouses. The objective of the analysis is the determination of such locations of warehouse facilities in the analysed logistic network that the earlier adopted assessment criteria achieve concurrently the most beneficial of possible values.

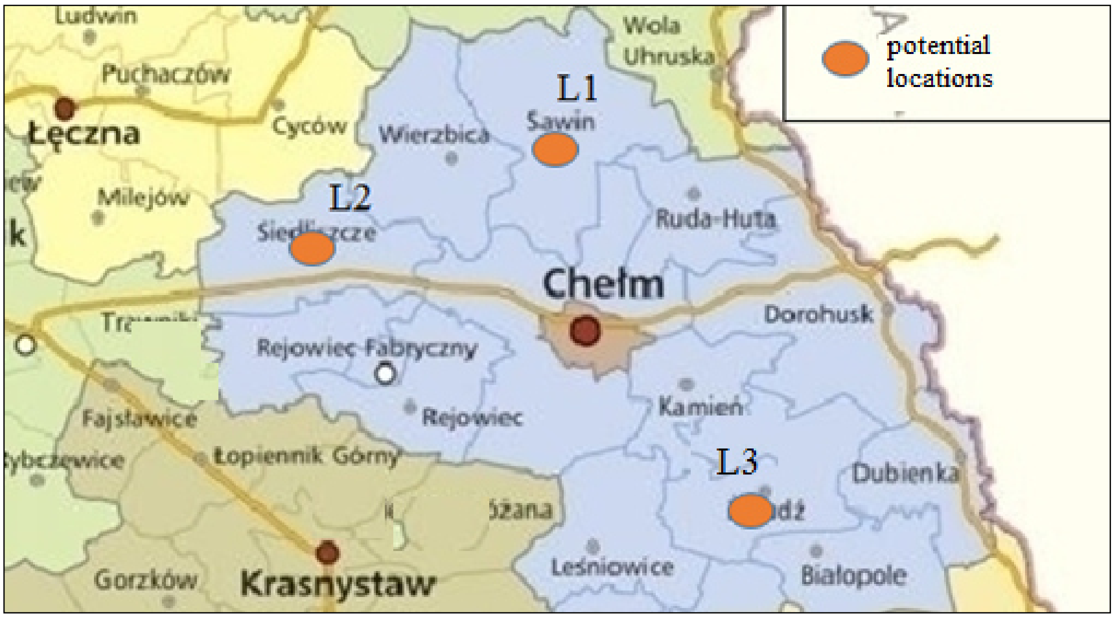


Figure 4 – Potential locations of warehouse facilities

Using the LogMND programme [9] five following variants were generated for the location of warehouses that satisfy the adopted limitations:

- variant 1 – location of warehouses L1 and L2,
- warrant 2 – location of warehouse L2,
- variant 3 – location of warehouses L1, L2, L3,
- variant 4 – location of warehouses L3 and L2,
- variant 5 – location of warehouses L1 and L3.

Values of selection criteria for particular variants of warehouse locations and the weights of those criteria have been presented in Table 1. According to earlier remarks, minimising applies to the criteria of transport and storage criteria, total length of the route and distances of warehouses from main transport routes, while maximising is applied to the land area designated for further expansion.

Table 1 – Assessment criteria of variants for the location of warehouses and their weights and values for particular variants

Assessment criterion of location variants f	Weight of criterion $c(f)$	Variant of warehouse location				
		$l = 1$	$l = 2$	$l = 3$	$l = 4$	$l = 5$
1	35	25 000	30 000	32 000	40 000	42 000
2	30	620	750	700	960	990
3	15	2500	3000	1500	3000	2000
4	20	30	50	40	60	25

Results of standardisation of variant assessments were presented in Table 2, while the assessment of warehouse location variants in Table 3.

Table 2 – Results of implemented standardisation of variant assessments

Criterion	Variant of warehouse location				
	l = 1	*l* = 2	*l* = 3	*l* = 4	*l* = 5
1	10.00	8.33	7.81	6.25	5.95
2	10.00	8.27	8.86	6.46	6.26
3	8.33	10.00	5.00	10.00	6.67
4	8.33	5.00	6.25	4.17	10.00

Table 3 – Assessment index for adopted location variants

Criterion	Variant of warehouse location				
	l = 1	*l* = 2	*l* = 3	*l* = 4	*l* = 5
1	3.50	2.92	2.73	2.19	2.08
2	3.00	2.48	2.66	1.94	1.88
3	1.25	1.50	0.75	1.50	1.00
4	1.67	1.00	1.25	0.83	2.00
$W(l)$	**9.42**	**7.90**	**7.39**	**6.46**	**6.96**

Table 3 shows that according to the determined weights, the most optimum location variants of those subjected to the analysis is variant 1. The major role in the selection of that location variant was played by criteria of costs and of the minimum length of forwarding job routes, in accordance with the adopted weights of decision-making entity's propriety weights.

5. CONCLUSIONS

Location of warehouse facilities within the logistic network is a complex multi-criteria decision-making problem. The diversity of optimising criteria in the analysed problem imposes the necessity of applying in this case the above mentioned multi-criteria decision-making assistance to select the final location variant. As regards the single-criterion, the issue of particular importance in finding the optimum solution is adopting the appropriate optimising algorithms. Quite frequently in complex location problems use is made of heuristic algorithms. This type of algorithms does not assure an optimum solution in each and every case, frequently are limited to the determination of a sub-optimal solution. On the other hand, for the multi-criteria assessment of particular importance is the selection of criteria weights for variant appraisal.

6. ACKNOWLEDGEMENTS

The scientific work carried out in the frame of PBS 3 project "*System for modeling and 3D visualization of storage facilities*" *(SIMMAG3D)* financed by the NCBR.

7. REFERENCES

[1] Akinc, U., Khumawala B.M.: *An efficient branch and bound algorithm for the capacitated warehouse location problem*, Management Science 23(6)(1977), 585–594.

[2] Brandeau, M.L., Chiu S.S.: *An overview of representative problems in location research*, Management Science 35(6)(1989), 645–674.

[3] Sharma, R.R.K., Berry V.: *Developing new formulations and relaxations of single stage capacitated warehouse location problem (SSCWLP): Empirical investigation for assessing relative strengths and computational effort*, European Journal of Operational Research 177(2) (2007), 803–812.

[4] Khumawala, B.M.: *An efficient heuristic procedure for the uncapacitated warehouse location problem*, Naval Research Logistics Quarterly 20(1)(1973), 109–121.

[5] Jacyna-Gołda, I.: *Chosen aspects of logistics network design method for production service companies*, International Journal of Logistics Systems and Management, Inderscience 15(2/3) (2013), 219–238.

[6] Ambroziak, T., Jacyna M., Wasiak M.: *The Logistic Services in a Hierarchical Distribution System*. In. Goulias K.: *Transport Science and Technology*, Elsevier 2006, 383–393.

[7] Geoffrion, A.M., Graves G.W.: *Multicommodity distribution system design by Benders decomposition*, Management Science 2(1974), 82–114.

[8] Sharma, R.R.K.: *Modeling a fertilizer distribution system*, European Journal of Operational Research 51(1991), 24–34.

[9] Wasiak, M.: *Metoda wielokryterialnej oceny obsługi logistycznej rejonu w wieloszczeblowym systemie dystrybucji*, Rozprawa doktorska, Politechnika Warszawska Wydział Transportu, Warsaw 2004.

[10] Wasiak M.: *Optymalizacja hierarchicznego systemu obsługi logistycznej (w: Modelowanie elementów i systemów transportowych)*, Prace Naukowe Politechniki Warszawskiej. Transport, vol. 56, Oficyna Wydawnicza Politechniki Warszawskiej, Warsaw 2006, 5–24.

[11] Hansen, P.H., Hegedahl B., Hjortkjær S., Obel B.: *A heuristic solution to the warehouse location-routing problem*, European Journal of Operational Research, 76(1) (1994),111–127.

[12] Perl, J., Daskin M.S.: *A warehouse location-routing problem*, Transportation Research Part B: Methodological 19(5) (1985), 381–396.

[13] Jacyna, I.: *Metoda projektowania sieci logistycznej dla przedsiębiorstw produkcyjnych,* Doctoral dissertation, Wydział Transportu Politechniki Warszawskiej, Warsaw 2011.

[14] Ambroziak, T., Żak J.: *Metoda wyznaczania optymalnej lokalizacji centrów logistycznych w wybranym obszarze usług logistycznych*, Prace Naukowe Politechniki Warszawskiej, Transport, vol. 60, Oficyna Wydawnicza Politechniki Warszawskiej, Warsaw 2007, 67–75.

[15] Demirel, T., Demirel N., C., Kahraman C.: *Multi-criteria warehouse location selection using Choquet integral*, Expert Systems with Applications 37 (2010), 3943–3952.

[16] Jacyna-Gołda, I., Santarek K., Wasiak M.: *Location of warehouse facilities in the logistics network*, w: J. Feliks (ed.), Conference Proceedings Carpathian Logistics Congress, Tanger, 2013.

[17] Wasiak, M.: *Praktyczne aspekty zastosowania sieciowej metody lokalizacji obiektów*, Logistyka 4 (2010).

[18] Wasiak M., Jacyna-Gołda I., Żak J.: *Metodyka lokalizacji magazynów w sieci logistycznej*, Logistyka 4 (2015), 1143–1152.

[19] Dey B., Bairagi B., Sarkar B., Sanyal S.K.: *Warehouse location selection by fuzzy multi-criteria decision making methodologies based on subjective and objective criteria*, International Journal of Management Science and Engineering Management 0 (2015), 1–17.

[20] Roy, B.: *Wielokryterialne wspomaganie decyzji*, Wydawnictwo Naukowo-Techniczne, Warsaw 1990.

[21] Zeleny, M. (ed.): *Multiple Criteria Decision Makin,* McGraw-Hill, New York 1982.

[22] Jacyna M.: *Multicriteria evaluation of traffic flow distribution in a multimodal transport corridor, taking into account logistics base service*, Archives of Transport 11(3–4)(1999), 43–66.

[23] Jacyna, M. (collective work): *Kształtowanie systemów w wybranych obszarach transportu i logistyki*, Oficyna Wydawnicza Politechniki Warszawskiej, Warsaw 2014.

URBAN COMMUNICATION BEHAVIOR AMONG CRACOW STUDENTS OF STATE UNIVERSITIES

Elżbieta WYRAZ[1], Małgorzata KUŹNAR[2]

[1]Cracow University of Technology, Logistics Systems Division, Cracow, Poland
[2]Cracow University of Technology,
Reliability and Technical Exploitation Division, Cracow,
Poland

Abstract:

Analysis of the most frequently selected transportation modes within the city is an important aspect of urban logistics and allows to estimate the popularity of the transportation modes. It is particularly important in shaping the distribution of traffic flows, taking into account the principles of sustainable development. The purpose of this study was a communication behavior analysis. The research group consisted of 3013 Cracow State Universities students who responded the questionnaire. Assessment of expectations and preferences of travelers taking into account the direction, distance and travel motivation has been presented. The results provide a basis for the development of appropriate behavior of communications.

Keywords:

urban transportation modes, communication behavior, quality of public transport services, timetables of traffic flows, sustainable development

1. INTRODUCTION

In an era of continuously progressive increase in the number of vehicles on the road, the analysis of the choice of methods of movement within the city, as in the inter-city travel is becoming increasingly important. An appropriate policy for the city renovations and investments in the creation and development of alternative means of transport contributes to reducing traffic congestion and popularization of environmental protection. Public transport, cycling and hiking trips in comparison with passenger cars positively affect the ecological aspects [1]. Analysis methods of movement allows to know the behavior of communication and motivation travelers. Which in turn is the basis for determining the appropriate transport policy and communication center.

According to the Automotive Market Research Institute SAMAR in 2015 Poles have registered 352,518 new passenger cars [2]. It is about 8.09% more than in the previous year. As a result, there are becoming more frequent obstacles on the road and increasing negative impact on the environment can be noticed.

2. FACTORS AFFECTING THE CHOICE OF TRANSPORT

The choice of transport affects communication behavior. They are determined mainly by motivation and direction of movement and distance. Decision problems determine factors such as age, gender, employment status, income, marital status, social group (eg. a group of professional, school children), and most of all the current opportunities (factor of owning a car or other means of transport), restrictions, customs, and sometimes social and cultural [3–8].

The choice of transport is largely dependent on qualitative factors that are subjective assessment of each traveler. These include [9]:

- time – total travel time, time to reach and waiting for a transport mode, time to reach from the mean of transport the destination,
- distance – the distance between the place of origin and destination, taking into account the distances involved in the movement "to" and "from" space means of transport,
- availability – owning a car, the location of a parking space, the number of transfers, frequency, time of day,
- finance – the total cost of transportation,
- atmospheric conditions – temperature, rainfall, snowfall, slippery surface, pressure,
- safety – subjective feeling of personal safety and the safety of transport,
- comfort – a subjective assessment of the behavior of personal space, having a seat, possibility to adjust a temperature (air conditioning), perform other tasks while traveling and so on.

All the above mentioned factors to a greater or lesser extent, affect the decisions of travelers. Often, however, the choice of transport is affected by cultural and social characteristics, personal habits, as well as the well-being and psychological barriers.

3. METHOD OF URBAN COMMUNICATION

In the urban area, depending on the size and development of the city transportation we distinguished above all 5 methods of movement. These include:

- cars,
- wheelers – scooter, bike, motorcycle,
- urban public transport – buses, trams, metro,
- cycling – private or city bicycles,
- walking trip.

Table 1 shows the advantages and disadvantages selected for each of the means of transport.

The pros and cons are subjective assessment of each traveler. Depending on the factors listed in section 2 for the means of transport, some advantages and disadvantages may be present or not.

Table 1 – Selected advantages and disadvantages for each type of transport [10,11]

Type of transport				
Cars	Urban public transport	Wheelers	Cycling	Walking trip
Advantage				
➢ Deciding about departure time and route ➢ Short travel time to destination point ➢ A sense of comfort and security from foreign ➢ A one-man journey or in the company load capacity ➢ Independent of atmospheric conditions	➢ Low cost, does not require a car ➢ Observation of the environ ment ➢ Conversation withother passengers ➢ The ability to perform other tasks during the journey, such as a phone call or reading a book	➢ Cheaper alternative than a car ➢ Deciding on departure time and route ➢ Short travel time to your destination ➢ Small dimensions allow you to move even the narrow streets	➢ No maintenance costs, as in the case of a passenger car and cycle ➢ Deciding on departure time and route ➢ Small dimensions allow you to move even the narrow streets ➢ Positive aspects that affect the health ➢ environment friendly	➢ No costs ➢ Deciding on departure time and route ➢ The ability to perform other tasks while on the move ➢ Positive aspects that affect the health ➢ environment friendly ➢ Observation of the environ ment ➢ Talk with other pedestrians
Disadvantages				
➢ The high cost of maintenanc e ➢ A negative impact on the environme nt at large congestions on road ➢ Full concentration while driving	➢ Reduce capacity congestion in transport mode ➢ The frequent lack of seats ➢ Waiting at bus stops ➢ Low safety ➢ Inability to decide on the time and route	➢ Reduce capacity ➢ Full concentration while driving ➢ Lack of communica tion with others while driving ➢ Dependence on weather conditions	➢ Low safety ➢ Long travel at ➢ greater distances fatigue ➢ Dependence on weather conditions ➢ Reduce capacity	➢ Low safety ➢ Long travel at greater distances fatigue ➢ Dependence on weather conditions ➢ Limitations to the size and weight of luggage, shopping etc.

4. APPLIED RESEARCH

Analysis of the choice of transport allows to travel around the city narrowed to a randomly selected group of students of several Cracow universities. The choice of the city was determined by a relatively high ratio of students to the city's inhabitants, high number of students in comparison with other cities, as well as the long tradition of academic centers. Moreover, Cracow, as a city characterized by multiculturalism is also attracts for many tourists. All this makes the choice of an appropriate communication policy of the city very important.

To make the results reliable, focus was on one motivation of travel (home-school, school-home). This choice was driven features of the student community – often occurring lack of communication habits caused by eg. change of residence in the case of not locals students, travel to family homes and so on.

In this article data from the conducted for this purpose questionnaire surveys relating to urban traveling has been used. The research include both Internet and direct questionnaire surveys. Tested population was a statistical representation of 3013 Cracow students (representative sample). The questionnaire consisted of a series of questions about the type and course of study, the most popular means of transport, assessing the quality of travel and so on.

Figure 1 illustrates the real ratio between the number of full-time and part-time students and first- and second-degree studies for the Malopolska region in the academic year 2014/2015.

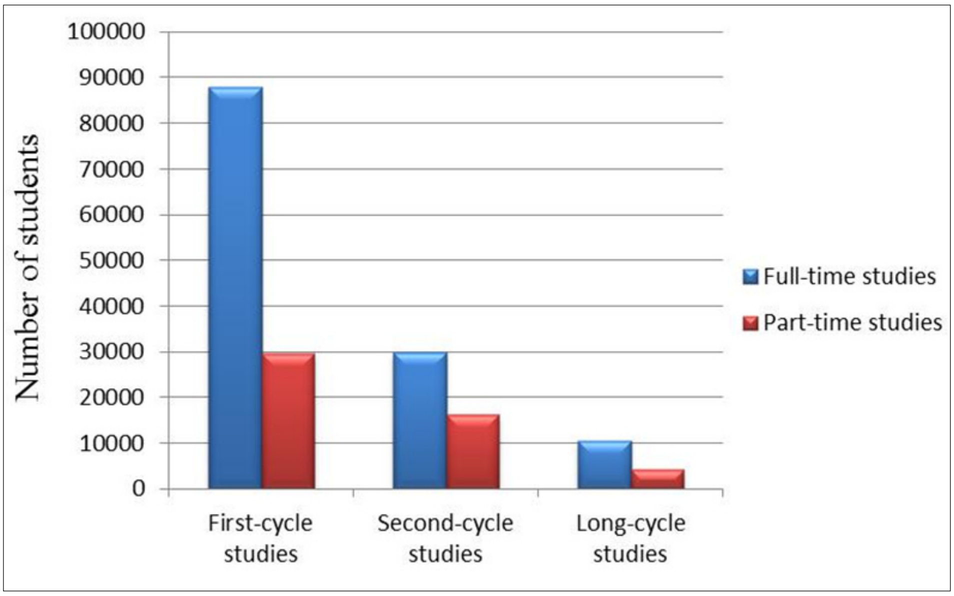


Figure 1 – Distribution of students due to the course and mode of study in the years 2014/2015 in Malopolska [12]

On the first degree studies a regular students accounted for about 75%, while on the second-cycle studies, there was a decrease of approximately 12%. This decline is caused primarily by the employment of graduates of the first degree. Non-regular students account for about 28% of Cracow students. Taking into account the above limitations applied among the respondents (mainly motivation of trip) and that about 71% of journeys in the city are made by cars, students of extramural studies have not been examined. Table 2 shows the percentage breakdown by the type of school, taking into account the statistical data from the Statistical Office in Cracow and the results of the surveys.

The survey had a part character, and has been carried out on certain selected elements of the population. The results are similar to the statistical data. They show that the largest group are students of technical and engineering school (25.1%).

Table 2 – Structure of students of higher education institutions by type of schools in the academic year 2014/2015

Type of school	Statistical data [%]	Survey data [%]
economic and administration	16.7	18.1
humanistic & law	8.8	8.0
medical	6.8	6.5
pedagogical	6.1	6.0
production and processing	6.8	6.5
social	12.0	15.0
technical and engineering	23.5	25.1
others	19.3	15.0

5. RESULTS AND ANALYSIS

Analysis the results of the survey are presented in graphs. Table 3 shows the percentage share of transport modes, depending on the field of study among students of Cracow universities.

Table 3 – Percentage structure of the selected means of transport among the students of Cracow universities by field of study in the academic year 2014/2015 [12]

Type of school	Car [%]	Urban transport [%]	Bicycle [%]	On foot [%]	Others [%]
economic and administration	21.8	60.4	6.1	7.8	3.9
humanistic & law	30.1	57.6	3.2	4.5	4.6
medical	32.3	52.2	3.1	3.9	8.5
pedagogical	22.1	60.1	4.7	6.1	7.0
production and processing	22.9	58.8	4.9	7.4	6.0
social	20.0	64.3	3.8	7.6	4.3
technical and engineering	21.4	63.3	4.1	7.3	3.9
others	23.8	58.7	3.6	5.2	8.7
$\bar{x}$	**24.3**	**59.4**	**4.2**	**6.2**	**5.9**

Presented data represent an average percentage values for the course of study (first and second degree, long-cycle studies). Compared with the results of the Comprehensive Research Movement [13], can be noticed a significant difference in the results. The students as a special social group (adult, but usually do not have their own income) taking into account a trip motivation, home-school, school-house, far more likely use public transport (59.4%). Compared with the results of the Comprehensive Research Movement this value is higher by 23.1%, as is shown in Table 4. To a large extent it is caused the lack of their own income, a large number of transport links as well as discounts on travel (51% discount for students from standard fare).

Table 4 – Percentage structure of choice of transport – survey data and statistics

	Car [%]	Urban transport [%]	Bicycle [%]	On foot [%]	Others [%]
Survey data	24.3	59.4	4.2	6.2	5.9
Staticstical data	33.7	36.3	1.2	28.4	0.4

Table 5 shows values for each of qualitative factors with respect to the most commonly chosen transport means. Despite the significantly lower share of passenger cars compared to public transport, they received the highest average evaluation of all factors (2.7) – assuming that the value of 1 is the worst rating, 2 is the average rating, 3 is the highest rating. The lowest score was recorded for pedestrian travel – 1.9. It has been observed that walking trips chose students living in close proximity with the university, eg. in the student dormitory. While Table 6 contains the importance of factors determining the choice of means of transport. As in the previous case, the assessment was 1, 2 or 3 for each factor, with the assumption that each mark must be at least two times used. On this basis the average weight for each factor has been estimated.

Table 5 – Assessment of transportation among students of Cracow universities

	time	distance	availability	finance	atmospheric conditions	safety	comfort	$\bar{x}$
car	2.9	2.8	2.9	1.2	3.0	3.0	2.9	2.7
urban transport	2.1	2.2	2.1	2.9	2.3	2.3	1.9	2.3
bicycle	1.2	1.5	2.2	2.9	1.5	2.2	2.5	2.0
on foot	1.1	1.4	1.5	3.0	1.9	2.8	1.8	1.9
others	1.8	2.2	2.4	1.9	2.1	2.4	2.3	2.2

Table 6 –Weight of individual factors

	time	distance	availability	finance	atmospheric conditions	safety	comfort
value	2.8	2.4	2.4	2.9	2.0	1.9	2.6

On the basis of dependence of individual assessments of factors, it can be estimated, which is important for traveling and on that basis a development of communication policy of the city can be made. The above table shows that students do not evaluate bad traveling by public transport, which is the highest percentage among the respondents. The most important factor in the choice of public transport is the total cost of transport – monthly half-price ticket costs PLN 47 (allows you to travel tram and bus lines in the city zone), and the average monthly costs associated with travel by car is about PLN 250–350. Financial aspects are also highest rated of all the factors influencing the choice of means of transport. Improvement of travel comfort (air conditioning, heating, seating, modern fleet), accessibility (communication connections, service frequency) and the journey time would allow for greater participation and evaluation of public transport among the respondents. However traveling by car is still the most attractive for them despite the low assessment of the cost of travel.

In the case of cycling trips in the overall rating is 2.0. This result is caused due to, inter alia, small number of bike stations around the universities, both for private bicycles and city bikes (KMK

Bike). Cracow as a first city in Poland has launched a pilot installation which allows for bike hire from a special stations in the city center. In the season of 2014 there were over 300 000 lends. This demonstrates the growing popularity of alternative means of transport limiting the negative impact on the environment. Taking into account the planned until 2018, increasing the number of stations (from 34 to 150) and bicycles (from 300 to 2000), this number in the coming time should significantly increase.

6. CONCLUSIONS

Conducted questionnaire survey aimed to obtaining information about the transport behavior of students of Cracow universities. The results of conducted surveys allow for the selection of appropriate communication policy of the city, which translates into reducing costs and protecting the environment. Research have shown that for the test group the most important factors influencing the choice of means of transport are finance, time and comfort. In contrast, the most popular choice of transport is public transport. This choice is determined mainly by the lack of own funds and the discount on public transport.

The choice of means of transport among students depends on a number of factors, direct and indirect. However, selections of transport mode and the importance of the factors which made the surveyed group, may be different depending on the research group. Therefore, the shaping of the city's communication policy should carried out several studies on individual groups and determine their participation in city traffic.

7. REFERENCES

[1] Woodcock, J., Edwards P., Tonne C., et al.: *Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport*, Lancet, 374(2009), 1930–1943.

[2] Michalak, M.: *Jakie nowe auta kupują Polacy? Przegląd segmentu*, http://www.strefabiznesu.polskatimes.pl/, 02-02-2016.

[3] Buehler, R.: *Determinants of transport mode choice: a comparison of Germany and the USA*, Journal of Transport Geography, 19(2011), 644–657.

[4] Limanond, T., Butsingkorn T., Chermkhunthod Ch.: *Travel behavior of university students who live on campus: A case study of a rural university in Asia*, Transport Policy, 18(2011), 163–171.

[5] Lu, X., Pas E. I.: *Socio-demographics, activity participation and travel behavior*, Transportation Research Part A, 33(1999), 1–18.

[6] Zhang, M., Sun Q., Chen J., Guo J.: *Travel behavior analysis of the females in Beijing,* Journal of Transportation Systems Engineering and Information Technology, 8(2)(2008), 19–26.

[7] Choocharukul, K., Van H. T., Fujii S.: *Psychological effects of travel behavior on preference of residential location choice,* Transportation Research Part A, 42(2008), 116–124.

[8] De Bruijn, G.J., Gardner B.: *Active commuting and habit strength: an interactive and discriminant analyses approach*, Am. J. Health Promot, 25(3)(2011), 27–36.

[9] Sierpiński G.: *Zachowania komunikacyjne osób podróżujących a wybór środka transportu w mieście*, Prace naukowe Politechniki Warszawskiej, 84(2012), 93-106.

[10] Wyraz, E., Kuźnar M.: *Analiza metod przemieszczania się w obrębie miasta Kraków*, Logistyka, 3(2015), 4954–4962.

[11] Grava S.: *Urban Transportation Systems*, Nowy Jork, McGraw-Hill 2002.

[12] Król D.: *Szkoły wyższe w województwie małopolskim w roku akademickim 2014/2015*, Urząd statystyczny w Krakowie, Opracowanie sygnalne, 10(2015).

[13] Szarata A.: *Kompleksowe badania ruchu w Krakowie w 2013 r. – wybrane wyniki*, Logistyka, 6(2014), 13798–138005.

MAKING AN EFFICIENT LAST MILE DELIVERY SYSTEM IN JAPAN

Yuji YANO[1], Minoru SAITO[2]

[1]Ryutsu Keizai University, Faculty of Distribution and Logistics Systems
120 Ryugasaki-shi, Ibaraki,
Japan
[2]Kanagawa University, Faculty of Economics
3-27-1 Rokkakubashi Kanagawa-ku, Yokohama,
Japan

Abstract:

Parcel delivery providers in Japan are being confronted with the serious issue of the need to re-deliver up to 19.6% of all parcels. This is not only an environmental problem and an added expense for a company, but a labor problem due to the shortage of delivery personnel. This paper will examine possible ways to make the "last mile" more efficient. One such option is to make a new system where detailed information can be exchanged and/or alternative methods for receiving ones parcels.

Keywords:

cargo transport, e-commerce, last mile, parcel delivery

1. BACKGROUND AND OBJECTIVES OF THE STUDY

Internet commerce has been expanding rapidly in Japan due to mail-order and online sales activity. This dramatic growth has created "last-mile" delivery problems for logistics providers. The "last-mile" is a term used to denote delivery from the nearest distribution center to the customers' home. The rapid growth in the volume of parcels has exacerbated a labor shortage of experienced truck drivers. The final mile delivery process is particularly inefficient as it must be delivered a second time when a customer is not at home. Parcel delivery services do not charge for re-delivery in Japan and this, in itself, contributes to the high number of re-deliveries. Many customers would like to have other delivery options, apart from having a parcel delivered to their homes.

In light of these problems, the Japan Ministry of Land, Infrastructure, Transport and Tourism launched a project in fiscal 2015 to examine the alternatives available for parcel delivery. This paper will examine the impact of re-deliveries on the logistics industry, and consider options for making it more efficient.

2. INTERNET COMMERCE AND HOME PARCEL DELIVERY CONDITIONS IN JAPAN

2.1. Internet commerce market growing rapidly

The Internet commerce market in Japan generated around ¥6.15 trillion ($56 billion USD) in sales during fiscal 2014 and accounted for 4.4% of all retail sales in the country. The market has grown by some 42.7% over the past five years, and is a common shopping option for most people. It is estimated that the Japanese adults purchase an item online on average 8.9 times per year. Amazons entry into the market has had a very big, impact ever since the company opened its first book retailing site on November 1, 2000. The range of items carried by Amazon has expanded steadily, and now encompasses some 50 million individual products. Sales in 2015 rose 4.4% year on year, to about ¥1 trillion ($83 billion USD).

Amazon has delivered all items purchased in Japan free of charge since November 2010 and most other online retailers have been forced to follow in order to remain competitive. However, Amazon revised this policy in April 2016 when it began charging a flat fee of ¥350 ($3.2 USD) for shipping any single order with a total sales value of less than ¥2000 ($18.3 USD). Amazon Prime customers are exempt from this charge.

2.2. History of Japan's parcel delivery industry

The pioneers of Japan's parcel delivery industry began offering home delivery services in the mid-1970s, and as of 2014 this industry was delivering 3.6 billion parcels a year. The market has grown by 15.2% over the five-year period from 2009–2014. The statistics above cover parcel delivery from business to business, business to consumer and consumer to consumer. This works out to 28.5 parcels per person, per year on a per-capita basis. Parcel delivery has become an essential part of life.

The parcel delivery industry in Japan is highly concentrated, with just three companies handling 92.5% of all deliveries. In fiscal 2014, top-ranked Yamato Transport Co., Ltd. handled 1,622 million parcels, or 45.4% of the total; Sagawa Express Co., Ltd. delivered 1,196 million parcels, or 33.5%; and, Japan Post Co., Ltd. delivered 485 million, or 13.6% of the total.

Japan is a relatively small country, so deliveries between most major cities are typically handled overnight, as standard. Most services also deliver packages directly to the customer's doorstep, handing the package to the recipient in person. Most parcel delivery services also allow the client to specify the delivery time at no additional charge. Table 1 shows the delivery schedules offered by each company. As the table below shows, customers can specify a very precise time window for the package to be delivered.

Table 1 – Delivery Time Schedules of Japan's Three Major Parcel Delivery Services

Yamato Transport	AM	12:00–2:00PM	2:00–4:00PM	4:00–6:00PM	6:00–8:00PM	8:00–9:00PM	
Sagawa Express	AM	12:00–2:00PM	2:00–4:00PM	4:00–6:00PM	6:00–8:00PM	6:00–9:00PM	7:00–9:00PM
Japan Post	AM	12:00–2:00PM	2:00–4:00PM	4:00–6:00PM	6:00–8:00PM	8:00–9:00PM	

The typical rate for standard-size parcels delivered between Tokyo and Osaka (roughly 500km) is ¥864 ($7.90 USD) for parcels under 2kg with total dimensions of (L x W x H) less than 60cm. The cost is ¥1,296 ($11.80 USD) for parcels under 10kg with total dimensions of up to 100cm. The competition among the leading parcel delivery services is very severe. In order to win contracts from online retailers, most offer flat fees of as little as ¥300 ($2.7 USD) per parcel. The average charge per parcel delivered fell from just under ¥590 ($5.4 USD) in 2008 to about ¥530 ($4.8 USD) in 2012, but it has been rising since then and now averages ¥545 ($5.0 USD) in 2013. The intensity of price competition can be seen in Amazon's delivery policies. Prior to 2015 the company delivered a large volume of parcels using both Yamato Transport and Sagawa Express. In 2015, however, Sagawa Express proposed a hike in rates, citing the rising cost of personnel. Negotiations broke down and since then Yamato Transport has handled almost all of Amazon's business, though latter company's rates have risen (Yamato Transport).

3. RE-DELIVERIES AND THEIR IMPACT

3.1. Frequency of re-deliveries

A sample survey of the three major parcel delivery companies (see Table 2 below) showed 19.6% of all parcels sent to residential addresses had to be re-delivered because a recipient was not home. Furthermore, while 15.7% of the total re-deliveries were successful on the second attempt, 2.6% had to be delivered a third time, and 0.8% had to be dispatched four or more times. In major cities, where a large percentage of people live alone, 21.6% of the parcels needed to be re-delivered at least once, whereas the ratio in suburban residential neighborhoods was 18.4% and in rural areas, just 15.8%. Though there was some disparity, the rates of re-delivery did not change dramatically from region to region. Even in rural areas, re-delivery rates are a problem. The fact that 3.5% of parcels had to be delivered more than twice is a particular concern. Although most parcel delivery services allow customers to specify the delivery time, and many retailers offer customers the option of specifying the date or time, in practice only 18% of such deliveries had a time specified. More importantly, even in cases where a time was specified, the re-delivery rate was still a high 17.0%, showing that this is not a reliable way to address the issue.

3.2. Reasons for re-delivery

The Ministry of Land, Infrastructure, Transport and Tourism conducted a survey to determine the main reasons for re-deliveries. In cases where a re-delivery was needed, a large percentage – 42% of all respondents – said that they "did not know that a parcel was being delivered." However, another 26% indicated that they knew a delivery was coming, but that they "had to leave home for some reason at the time of the delivery," and 14% indicated that they "knew they were going to be out when the delivery was made, but expected it to be re-delivered." In other words, some 40% indicated that the problem stems from consumer assumptions that a parcel will be re-delivered automatically. In addition, 28.4% of respondents said by using online retailers which allowed them to select the delivery time, they had reduced the number of times they needed to have parcels re-delivered. Although a large percentage of re-deliveries occur because the recipient is not aware that a parcel has been sent, it appears that part of the problem is that customers take it for granted that a parcel will be re-delivered.

Table 2 – Re-delivery Rates for Parcel Delivery Companies
(Note: Sample covers just 0.1% of all parcels delivered in FY2013. The total was 3.64 billion parcels.)

	Total parcels delivered	Successful delivery	At least 1 re-delivery	At least two	Three or more
Urban areas	1,777,732	1,394,407 (78.4%)	305,390 (17.2%)	56,128 (3.2%)	18,785 (1.1%)
Suburbs	2,035,861	1,661,388 (81.6%)	310,643 (15.3%)	45,431 (2.2%)	15,322 (0.8%)
Rural areas	323,294	272,293 (84.2%)	34,496 (10.7%)	5,353 (1.7%)	2,025 (0.6%)
All areas	4,136,887	3,328,008 (80.4%)	650,529 (15.7%)	106,911 (2.6%)	36,132 (0.9%)

3.3. Social and economic impact of re-deliveries

The next issue we will consider is the social and economic impact of excessive re-deliveries. Trial calculations can give us a picture of the environmental impact and effect on labor productivity. To analyze the impact of the re-deliveries, we begin by calculating a baseline figure, which would represent total distance travelled if all parcels were delivered successfully, the first time. This figure was then compared to the actual distance travelled. The calculations suggest that vehicles making repeat deliveries account for 25% of the total distance covered by parcel delivery vehicles. Using this figure as our basis for comparison, we can determine the additional CO_2 emissions caused by re-deliveries.

Based on data for the total number of packages delivered by parcel delivery companies, a delivery vehicle typically travels an average distance of 0.58 km for each package delivered. That figure is used to calculate the amount of additional travel a vehicle makes over the course of a year, just to handle re-deliveries. We have used a figure of 808/1,000,000t-CO_2/t・km as the average volume of CO_2 generated by a small commercial vehicle. This calculation indicates that an additional 420,000 tons of CO_2 is generated each year by delivery vehicles, solely to handle re-deliveries. In addition, we calculate that each re-delivered package, including all activities required to make the re-delivery, consumes 0.22 man-hours of labor. Using the assumption that all workers put in eight-hour work days, this adds up to a total of 180 million man-hours per year, or roughly the equivalent of 90,000 people working full time in a given year, just to handle re-deliveries. This is a serious drain on an industry that already faces a shortage of workers.

In 2015, the industry had a total demand for drivers that is equivalent to 880,000 full-time workers, but the number of drivers available was just 740,000, leaving parcel delivery firms 140,000 employees short of full staffing and creating crisis conditions for the industry. All major companies are understaffed, and are urgently seeking new workers. In the July-September period, 19.1% of parcel delivery operators described their situation as "understaffed", while another 38.8% said they were "somewhat understaffed". The industry faced a particularly serious pinch in March 2014, as plans to raise the consumption tax sparked a surge of demand. In some cases, there was not enough capacity to deliver packages to customers. Companies were also not able to secure additional staff to handle demand from year-end gift deliveries in 2014, which caused delays in many parcel deliveries. Since wages are now rising in general, as shown in the government statistics (Ministry of Health, Labor and Welfare), companies with heavy exposure to personnel costs, such as parcel delivery companies, are facing serious difficulty. The additional labor required to handle re-deliveries will certainly push up costs.

4. ESTABLISHMENT OF A "LAST- MILE DELIVERY SYSTEM"

4.1. Overview of a "last-mile delivery system"

The basic themes underlying a "last-mile delivery system" are to design a structure that facilitates better communication between online retailers, parcel delivery companies and consumers. The idea is to deliver precise information on the desired time and date of a delivery, as well as to offer consumers a wider range of options for receiving their deliveries. The former issue can be addressed mainly through the development of better software solutions, but the latter issue requires changes in both software and hardware, and in the design of the system itself. Since the social and economic costs of re-deliveries are very high, as already noted, it is essential to change the attitudes of consumers. The important thing is to consider ways to redesign the entire last-mile delivery system in ways that can address the re-delivery problem.

a. Establishing systems to allow transport companies and consumers to exchange detailed data on delivery times and dates

A system that allows parcel delivery companies and consumers to share information on planned delivery times, and the time/date that the consumer is available to accept delivery, will help reduce the number of parcels that need to be re-delivered.

b. Establishing systems that include alternate methods of receiving or collecting a parcel

A variety of possible alternatives to home delivery could be considered, such as allowing consumers to pick up their parcel at a convenience store near their home or workplace; setting up parcel-collection "boxes" in multi-unit housing developments, at train stations or post offices, and so on.

c. Changing consumer attitudes

When parcels need to be re-delivered, it generates a negative impact and expense not only for the delivery company, but for society in general. It is essential that consumers be made more aware of and responsive to the fact that this increases the cost of the service.

4.2. Establishing systems to allow transport companies and consumers to exchange detailed data on delivery times and dates

The customer survey on reasons why a parcel needed to be redelivered showed a large percentage of respondents who either did not know a parcel was going to be delivered, or who knew they were going to be away from home, but assumed that the delivery company would deliver the package again on a later date. Looking at these responses, the first issue that needs to be addressed is to set up a user friendly, convenient system that can let consumers know that a parcel is going to be delivered, and ascertain the best time to make the delivery. The second issue is that customers do not want to be overly constrained by a delivery schedule. If for some reason they realize that they will not be at home to receive a parcel, they need a convenient and easy-to-use method of contacting the delivery company and changing the planned delivery time.

At present, Japan's leading parcel delivery companies have already established systems that allow customers to specify the time they wish to a parcel, free of charge. However, when purchasing items online, sometimes it is possible for the customer to indicate the desired delivery time, and sometimes it is not. Furthermore, even when such an option exists, many customers do not take advantage of the service. There are also many cases where a considerable period of time may pass between the date that a customer orders an item and the date it is shipped. It is necessary for parcel delivery companies and online retailers to collaborate, to set up a system that would remind customers that a shipment is coming, and encourage a larger percentage of them to specify the planned delivery time.

The largest parcel delivery company already has a service for registered members, which informs them by e-mail when a package is sent, and the planned time for delivery. If the customer is going to be unavailable at the intended delivery time, the current system allows them to change the planned delivery time, though only one change is permitted. Furthermore, the system is not responsive enough to handle sudden, last-minute changes, so the package may end up being unsuccessfully delivered at the wrong time. To address these shortcomings, in February 2016 the leading parcel delivery companies introduced a new service for customers who use the "LINE" social networking service (SNS), which permits changes to the delivery schedule to be made in real time. It is essential that this system be expanded, so that all consumers and parcel delivery companies can exchange data on delivery times and availability on a real-time basis.

4.3. Establishing alternate methods of receiving or collecting a parcel

A recent survey asked consumers to name "a method of delivering a parcel that would ensure you receive the parcel without fail, on the first attempt". The largest percentage of respondents indicated that picking up the package at a nearby convenience store would be the easiest method. Nearly 70% of respondents selected "picking up the package at the checkout counter of the convenience store closest to my home", and another 20% selected "picking up the package at the checkout counter of a convenience store close to my workplace" (respondents could select more than one option). In terms of options that do not require participation by another party, 60% indicated that they would like to "pick up the package in a numbered locker at a nearby convenience store", and 30% chose "pick up the package in a numbered locker at the nearest train station". Women were more likely to select an option that did not require interaction with another party. The responses show that it is important to consider possible alternatives to the current method of delivering packages to a customers' home (Ministry of Land, Infrastructure, Transport and Tourism).

4.3.1. Collecting a parcel from a convenience store

Convenience stores in Japan have already introduced ~~a~~ systems that allow them to perform a multitude of services on behalf of their consumers. These include ATM services for banks, fund transfer services that allow people to make tax, utility bill and other payments, ticket sales services, and many more. In addition, they already serve as representatives for postal and parcel delivery services, allowing people to send packages from their local store. There are currently about 54,000 convenience stores in Japan, and the majority are open 24 hours a day, 365 days a year. Some convenience stores have also offered parcel pick-up services as well, but this was restricted to a few business alliances between the convenience store chains, parcel delivery companies or online retailers. One potential concern is that alliances between convenience store chains and certain parcel delivery providers or retailers might limit the parcel companies which can deliver to a given convenience store. This may be an inconvenience for consumers. For example, the largest convenience store chain in Japan – Seven-Eleven Japan Co., Ltd. – has an exclusive contract to handle packages for Yamato Transport. The second-largest convenience store chain – Lawson, Inc. – has been working with Japan Post for some time, and as of July 2015, it now also does business with Sagawa Express. FamilyMart Co., Ltd also handles package dispatches for Yamato Transport, exclusively. Japan Post not only has access to some convenience store chains but also to post offices nationwide, giving it a total of 45,000 locations. In the future, the question is whether these barriers will remain, or whether convenience store chains will handle deliveries from all parcel delivery companies without bias.

4.3.2. Collection from a delivery box or locker

Another alternative method of receiving a package is to set up collection boxes to hold the parcel when a recipient is not home, allowing them to collect it whenever they chose to do so later. For example, in a multiunit housing block, the delivery person can input the recipient's room number, and select a box to hold the parcel. When the information is keyed in, the box door opens, the parcel is inserted and then the door is closed. The stamped delivery invoice is then left in the customer's mailbox. To open the box and collect the package, the recipient needs to provide some ID card or code number, to verify that they are the intended recipient. In recent years, the technology and network management for this sort of delivery box system has been spreading, making it possible to verify whether the box has or has not been opened, the condition of the equipment, etc. while at the same time ensuring the packages reached their intended destination. Existing delivery box use is extremely high, especially on weekdays, with capacity at over 100% on Mondays, Tuesdays and Wednesdays. As a result, it is often impossible to use the boxes to make a delivery. In multiunit housing developments where families live, people begin to collect parcels from the boxes around 4:00 PM, and collection peaks at 6:00 PM. The average amount of time a parcel spends in locations such as this is about six hours. However, in multiunit developments where most of the residents are single, people typically collect packages between 4:00PM and midnight, and only about 60% are picked up the same day they are delivered. The rest remain uncollected for a day or longer.

There is no data on the number of collection boxes that have currently been set-up nationwide. However, the largest manufacturer of these systems has installed boxes in 22,000 locations, primarily in multiunit housing complexes. Around 4.5 million people have access to these boxes. They are generally found in recently-built housing complexes sold by major real estate developers, with the majority found in high-end or luxury residences. Japan Post has developed specifications for a large-scale parcel collection box, and offers housing developers a fee ¥500 ($4.6USD) per home, to install boxes that conform to their standards.

In addition, larger capacity post boxes have been developed for individual houses, which are considerably larger than the conventional ones, and these are now gradually penetrating the housing market. Japan Post is working with housing manufacturers to improve standardization. Meanwhile, there have been some advances in delivery box installation in locations other than homes, such as train stations and post offices. Large online retailers have established ties to Japan Post, and are beginning to establish pick-up boxes exclusively for deliveries of their merchandise, at post offices nationwide. There has even been some discussion of ways to open up the network and establish collection boxes that can be used by multiple parcel delivery companies, rather than only Japan Post. The cost of setting up such boxes is rather high, so in order to promote their use, it makes sense for multiple companies to collaborate on installation.

4.4. Changing consumer attitudes

One of the most important issues that must be addressed is the fact that consumers take it for granted that packages will be delivered again, since they do not have to pay any extra fee for re-delivery. This perception is exacerbated by the fact that many online retailers promote services with the promise of "free delivery." This creates an inaccurate perception among consumers.

Many people fail to make sure they are home to collect a parcel because they are not aware of the waste and social cost their behavior creates, both to the environment and in terms of wasted labor. The problem was discussed at a Ministry of Land, Infrastructure, Transport and Tourism meeting in 2014, and this was reported widely on TV, in newspapers and other media. This report on the scale of the problem, and the social costs of re-deliveries, seems to have had some impact on consumer attitudes. It is essential that the information be publicized more thoroughly, as re-deliveries may force companies to increase their fees.

One potential way to drive home the message, and perhaps reduce the number of re-deliveries, is to begin charging additional fees when a parcel needs to be delivered a second time; however, delivery companies remain opposed to the idea. This may be because of concerns that it will elevate complaints about late deliveries – cases where parcels are not delivered within the specified time period. However, in a survey of consumers, about half indicated that they would be motivated to adjust behavior if there was an incentive for collecting a parcel on the first delivery attempt. About 50% said that an incentive of ¥100 ($0.9 USD) would be appropriate, and about 40% said that they would be influenced even if the incentive was less than ¥100. The comparative discount that parcel delivery companies could offer when a customer brings a parcel to their office for dispatch, rather than having it picked up, is around ¥100-¥120 ($1.10 USD), showing that incentives could have a positive impact.

5. COMMON PLATFORM

The chart below highlights what we discussed in our paper. It will also help us to establish a common framework of reference for discussion about the last mile. As shown in Figure 1, below; the common platform for last mile includes several functions which should help to reduce redelivery problems. In addition to usual home parcel delivery, several new services will also be added to the 'Common Platform' which is the black box in the middle of the figure. These additional services are parcel delivery services from shops, shopping services in cooperation with stores, and services for watching or monitoring the elderly.

In fact, in 2015, Yamato Transport started a pilot project in a suburb of Tokyo. In this project, Yamato and other parcel delivery companies deliver their parcels in cooperation with each other to reduce the losses incurred from the re-delivery of parcels. In addition to starting a cooperative parcel delivery with each other, logistic service providers will in the future be better connected to the stores and shops which are looking to offer their products for home delivery to their customers as well as offering the new additional service of monitoring the elderly. The diagram below outlines one possible organizational layout for a common platform of the last mile. It is expected a more excellent. The common platform which will eventually be put into use is expected to be much more excellent.

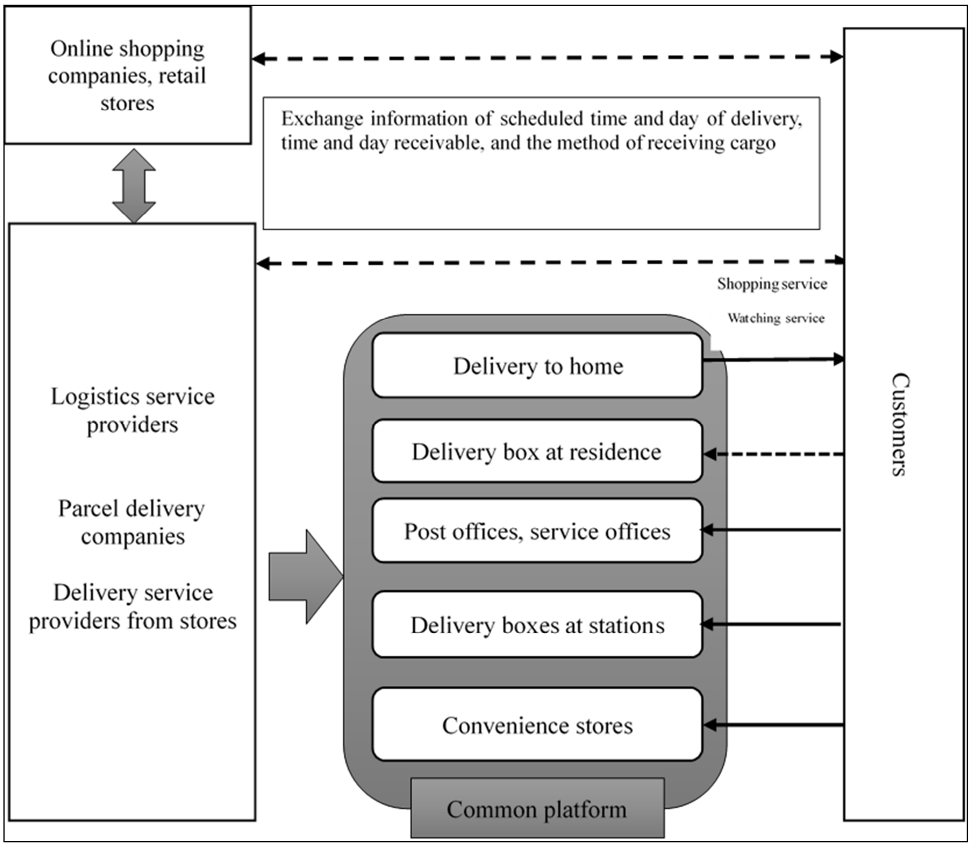


Figure 1 – Common platform for the last-mile

6. CONCLUSION

Parcel delivery services have become an essential part of daily life, and therefore it is necessary to start developing the business in a standardized way, as a part of the social infrastructure. There are many potential options that could be pursued, to improve the last-mile delivery system and reduce the inefficiencies and waste caused by re-deliveries. Some of these have already been put into place on at least a partial basis. However, there are limits to what a single parcel delivery company can do to address the problem if it continues to work independently. What is needed is a coordinated effort by all parcel delivery companies and online retailers, as well as associated industries like convenience stores, real estate companies, rail operators and the government to come together and establish a standardized last-mile delivery network that will benefit all parties. Cooperation in the development of such a shared platform which will prove beneficial to all who take part in it.

7. REFERENCES

[1] Duin, J., et al.: *Improving Home Delivery Efficiency by Using Principles of Address Intelligence for B2C Deliveries*, Transportation Research Procedia 12(2016), 14–25.

[2] Ducret, R., Delaître L.: *Parcel Delivery and Urban Logistics – Changes in Urban Courier, Express and Parcel Services: The French Case*, 13th World Conference on Transport Research, July 2013, 15–18.

[3] Hayashi, K., et al.: *The Development of the Parcel Delivery Service and its Regulations in China*, Procedia – Social and Behavioral Sciences, 125(2014), 186–198.
[4] Iwan, S., et al.: *Analysis of Parcel Lockers' Efficiency as the Last Mile Delivery Solution – The Results of the Research in Poland*, Transportation Research Procedia, 12(2016), 644–655.
[5] Kim, S., et al.: *Analyzing the cost efficiency of parcel distribution networks with changes in demand*, International Journal of Urban Sciences, 18(3)(2014), 416-–429.
[6] Liu, Q., Goh M.: TA-Q-BIN: *Service Excellence and Innovation in Urban Logistics*, Springer, Berlin, 2015.
[7] Loom, P. et al.: *A Comparative Analysis of Carbon Emissions from Online Retailing of Fast Moving Consumer Goods*, Journal of Cleaner Production, 106(1) (2015), 478–486.
[8] Ministry of Health, Labor and Welfare*, Basic Survey on Wage Structure*, 2015
[9] Ministry of Land, Infrastructure, *Transport and Tourism, Report on the Symposium to Promote Alternate Parcel Delivery Methods, to Reduce the Number of Re-deliveries, 2015*.
[10] Taguchi, E. Thompson R. (Eds.): *City Logistics-Mapping the Future*, CRC Press, Baca Raton, 2015.
[11] Yamato Transport, *Annual Report*, 2015

A MODEL OF LOGISTICS SERVICES WITH HETEROGENEOUS FIRMS

Arunas BURINSKAS[1], Aurelija BURINSKIENE[2]

[1]Vilnius University, Faculty of Economics
Sauletekio ave 9, Vilnius, Baltics,
Lithuania
[2]Vilnius Gediminas technical university
Sauletekio ave 11, Vilnius, Baltics
Lithuania

Abstract:

This expansion of e-commerce comes out to positive demand shock for logistics services in Baltics. The target of research is to analyze this growing market, demand for logistics services, and supply thereof. For this purposes, authors apply standard empirical industrial organization model of BLP together with some developments from models of monopolistic competition. The proposed empirical model deals with vertical differentiation of services in the market. Our empirical research shows that logistics services are differentiated significantly due to investments into the quality of services. Higher quality helps to keep leading position and lower marginal costs for the leader of market.

Keywords:

logistics services, couriers, market, model, industrial organization

1. INTRODUCTION

Over the last five years, Baltics has experienced a real revolution in e-commerce. Customers are increasingly accustomed to buy online, but still twice less than EU average. This expansion of e-commerce comes out to positive demand shock for logistics services in Baltics. Therefore, we observe increase in the variety of logistics services and prices in the field; and the growing market attracts more customers.

The target of the research is to analyze this growing market, demand for logistics services, and supply thereof. We are to identify the main features of logistics service market.

For this purposes, authors apply standard empirical industrial organization model of BLP together with some developments from models of monopolistic competition. The proposed empirical model deals with vertical differentiation of services in the market.

Over the last decade, industrial organizations mathematical modeling and empirical studies have focused on individual industries mostly. Therefore, industrial organization economists are interested in estimating customer behavior for several reasons. The first one is to measure changes in consumer welfare, the second one – to understand firm conduct. Regarding the relevance of differentiation, economists tend to have strong priors in many cases assuming that services are essentially identical. One of key lessons learned from the data is that this is not true: almost all services are differentiated.

Interestingly, the heterogeneity in choice correlates with standard customer attributes only weakly. Firm size, revenues, management skills explain some dimensions of choice obviously, but are far than enough to predict customer behavior accurately.

Our empirical industrial organization model reveals market structure, and market shares and power that rivals possess therein.

The proposed empirical model deals with vertical differentiation of services in the market. Our empirical research shows that logistics services are differentiated significantly due to investments into the quality of services. Higher quality helps to keep leading position and lower marginal costs for the leader of market.

The study begins with short literature review, than follows short model description, later on authors present results and conclusions.

2. A LITERATURE REVIEW

In the industrial organization theory, structural demand models are used to deal with logistics service differentiation. Veldman and Bückmann used logit model to quantify the routing choice and to derive from that a demand function to be used for port traffic forecasting and for the economic and financial evaluation of container port projects [1]. To deal with logistics service and costs to analyse 3PL behavior also binary logit models are used byTsai et al. [2]. Binary logit models as statistical approach focuses on generic variables such as service costs and performance, etc. and alternative specific variables such as firm size in sales and shipment size, etc [2].

As Chetty ([3]) and Heckman ([4]) and Einav and Levin ([5]) emphasizes that the structural models had the greatest impact for defining significant market.

Many studies begin by describing consumer behavior, often by estimating consumer demand for the services of relevant industry. The typical situation in the most industries is that consumers face the choice of services, which have many varieties. To estimate demand curves researches use BLP models that are the part of structural modelling from 1995 up to nowadays. What we get with the structural approach is the ability to test much finer hypotheses about consumer behavior.

The most popular models are the structural LOGIT differentiated service demand patterns.

However, consumer behavior testing in addition to standard logit also apply to common values (i.e. generalized extreme value), probit and mixed logit [6]. Often accompanied by the following probabilistic choice models used to apply to the number of econometric evaluation of supply, the technical and productive efficiency and other methods.

Probabilistic choice models with applications in researching customer behavior is considered to be McFadden ([7]), primarily for costumer behavior to establish causality. There are many factors that contribute to customer's choice: some of them are monitored by the investigator, while others – not. Therefore, these models are not deterministic, i.e. consumer choice is forecasted not entirely accurate, but only with a certain probability.

Berry, Levinsohn, and Pakes ([8]) proposed a standard logit differentiated service demand model (hereinafter – the BLP model), which, with various amendments and supplements to date remains the most popular among researchers.

The most popular interpretation of the error in the stochastic BLP model recognizes that consumer choices are deterministic, but the investigator's inability to define the behavior of customers accurately is included in the error, and that makes utility of customer stochastic in the view

of investigator. In order to estimate the well-specified model parameters, assumptions on the distribution of unobserved characteristics of customer shall be made and probability density integral is calculated, i.e. the probability of specific customer choices can be found.
Most often used industrial organization models with Bertrand or Cournot market equilibrium are not very practical, especially regarding the description of market equilibrium for logistics firms with differentiated service.

3. METHODOLOGY

Bellow is described the dynamic model, which primarily focuses on vertical differentiation of service. Differentiation is analyzed using empirical industrial organization generally applicable to simulation methods of demand. Based on simulation method is offered the prediction of demand and forecast methodology. Together is integrated model for determining demand, in conjunction with the supply detection methodology, which is used for the analysis of specific situations.

The proposed vertically differentiated service demand model is designed to keep both empirical demand and deterministic models of unity, continue to demand simulation model is oriented to Melitz, MJ, Ottaviano, GIP (2008) deterministic model quadratic utility and Berry, Levinsohn and Pakes (1995) empirical demand utility model (1–4) features:

$$u_{ijt} = x_j + \xi_j + v_{ix_{jk}} + \varepsilon_{ij}, \text{kai}: x_j + v_{ix_{jk}} \geq a_{ij} p_j \quad (1)$$

$$\delta_j = x_j + \xi_j \quad (2)$$

$$x_{ij} = x_{j,\max} - \beta_j \quad (3)$$

$$u_{ij} = v_{ix_{jk}} + \varepsilon_{ijt} \quad (4)$$

where: ξ_j – service features not observed by researcher, $v_{ix_{jk}}$ – buyer i marginal utility x_{ij} in respect to vector (when $v_{ix_{jk}} \sim Gum(0,\beta_j)$), ε_{ij} – errors, j – the number of differentiated services across the plurality Ω, α_i – buyer revenue marginal utility (in the model it is equal to 1), p – respectively j the size of the requested price vector, δ_j – expected value of utility by using j service, $x_{j,max}$ – the vector of maximum possible mode, when β_j=0, β_j – the standard deviation of the Gumbel distribution function for a variable when standard deviation – $\beta_j \pi / \sqrt{6}$, μ_{ij} – deviation from the expected utility values.

Such a model specification allows for modeling of differentiated goods demand functions depending only on each of their inherent consumer preferences in terms of value of goods distribution. The model assumes that both the company and the researcher is commonly known among buyers common brand evaluation, i.e. its expected value. But how commonly buyers evaluate the quality of the service for the company and / or investigator may not be known. The greater diversity of opinion on the value of services among buyers, the more is the buyer's marginal utility $v_{ix_{jk}}$ dispersion and demand curves slope (some examples presented in Figure 1 and Figure 2).

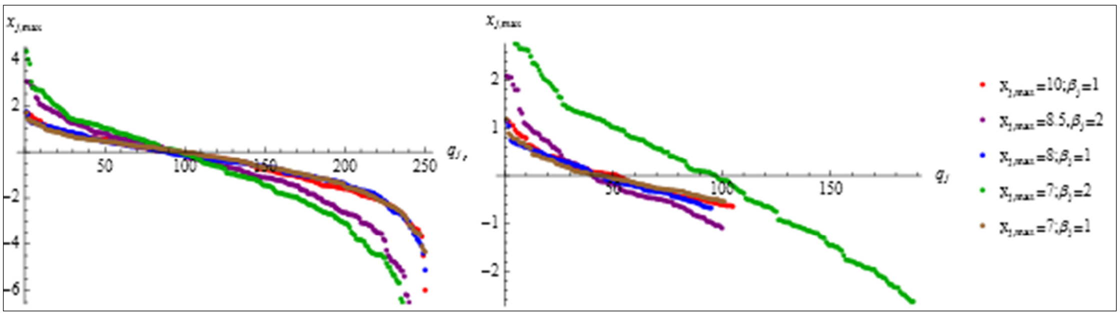


Figure 1 – Customers marginal utility $v_{ix_{jk}}$: on the left – all the buyers, on the right – which preferences are not lower than the price of service

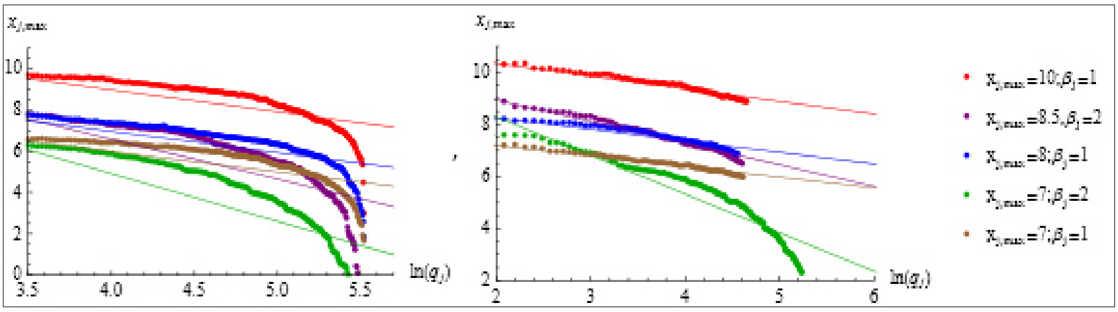


Figure 2 – Demand curve: on the left – all the buyers, the right – buyers whose priority is not lower than the price of service

For each service buyers marginal utility $v_{1x_{jk}}, v_{2x_{jk}}, v_{3x_{jk}}, v_{ix_{jk}}$ random sizes have the average $x_j - \gamma^E \beta_j$ (when γ^E is the Euler-Mačeroni constant) and constant variance $\beta_j^2 \pi^2 / 6$. In vertically differentiated service model, service price is determined by the introduction of demand redistribution of buyers choose the service, which is the value attributed to the buyer and the price difference is greatest. If there is no buyer spotlight than one service, which is the difference in the affirmative, the buyer does not buy any of the competing services.

Mixed LOGIT models provide an opportunity to describe the different features of customers behavior is described separately for categorization of different groups of customer's preferences. At mixed LOGIT models, which are specified under BLP model structure, it is allowed the correlation between a customer's preference (in μ_{ij}), while the parts of the model δ_j (which generally is made to this part of the model on β ratio) denotes the average customer preferences. Other errors assumptions remain the same as in the standard LOGIT models.

The mixed logit probability can be derived from utility-maximizing behavior in several ways that are formally equivalent but provide different interpretations. The most straightforward derivation, and most widely used in recent applications, is based on random coefficients (the example is provided in Figure 1). The decision maker faces a choice among *J* alternatives. The utility *U* of firm *n* from alternative *j* is specified as:

$$U_{nj} = v_{ix_{jk}} x_{ij} + \varepsilon_{ij} \tag{5}$$

where x_{ij} are observed variables that relate to the alternative and decision maker, β_j is a vector of coefficients of these variables for firm j representing that firm's tastes, and ε_{nj} is a random term that is iid extreme value. The coefficients vary over decision makers in the firm population with density $f(\beta)$. This density is a function of parameters θ that represent, for example, the mean and covariance of the β's in the population. This specification is the same as for standard logit except that β varies over decision makers rather than being fixed.

In mixed LOGIT models probability is described as standard logit probability L_{ij} integrals when integrating customer preferences coefficients β together with their probability density:

$$P_{ij} = \int L_{ij}(v_{ix_{jk}}) f(v_{ix_{jk}}) dv_{ix_{jk}} \tag{6}$$

Hensher and Greene (2003) and Train (2009) note that $f(v_{ix_{jk}})$ is specified as a continuous function. For example, $v_{ix_{jk}}$ probability density $f(v_{ix_{jk}})$ can be specified as a Gumbel distribution:

$$P_{ni} = \int \left(\frac{e^{-e^{\frac{a\left(x_l - \gamma^E \beta_l\right)}{b\beta_l} - \frac{1}{b\beta_l} v_{lx_{jk}}}}}{\sum_{j=1}^{J} e^{-e^{\frac{a\left(xj - \gamma^E \beta_j\right)}{b\beta_j} - \frac{1}{b\beta_j} v_{ix_{jk}}}}} \right) \varphi\left(\left(\beta \middle| b, W\right)\right) d\beta \tag{7}$$

$$f\left(v_{ix_{jk}}\right) = \frac{e^{-e^{\frac{v_{lx_{jk}}}{\beta_l}} + \frac{v_{lx_{jk}}}{\beta_l}}}{\beta_l} \tag{8}$$

where b is dispersion, W – average.

Mixed logarithmic probability is calculated by applying random coefficients method. Customers' preferences $v_{ix_{jk}}$ are distributed according to a probability density $f(v_{ix_{jk}})$ – parametres θ (for example, by mean and variation) function. These priority are not directly tracked by investigator, therefore unconditional selection probability is logarithmic $L_{ij}(v_{ix_{jk}})$ the integral of all possible variables $v_{ix_{jk}}$ basis.

The probability is approximated by using simulation $v_{ix_{jk}}$ where values and the use of probability density is $f(v_{ix_{jk}} | \theta)$; on the basis of each is calculated logarithmic likelihood $L_{ij}(v_{ix_{jk}})$. The simulations of probability $\breve{P}_{ij}$ is average of the sum of all services, sum of which is equal to one. From these simulations of probability further peak (maximum) is found between simulations of logarithmic maximum likelihood values *MSLL*:

$$MSLL = \max_{\ln \breve{P}_{ij}} \left(\sum_{i=1}^{I} \sum_{j=1}^{J} d_{ij} \ln \breve{P}_{ij} \right) \tag{9}$$

where: $d_{ij} = 1$, if the buyer i chooses the product j, and vice versa.

4. RESULTS

The analysis of logistics services in Baltic market shows such results: there are two markets (the first market is till 10 Eur per freight and the second one – from 10 to 40 Eur per freight). The first market is of small freights and the second one is of big ones (Figure 3). There are three players in the market: the market leader has revenue mainly from freights of small weight, and the other two market players get some revenues from freights of small weight and higher revenues from freights, which have higher weights.

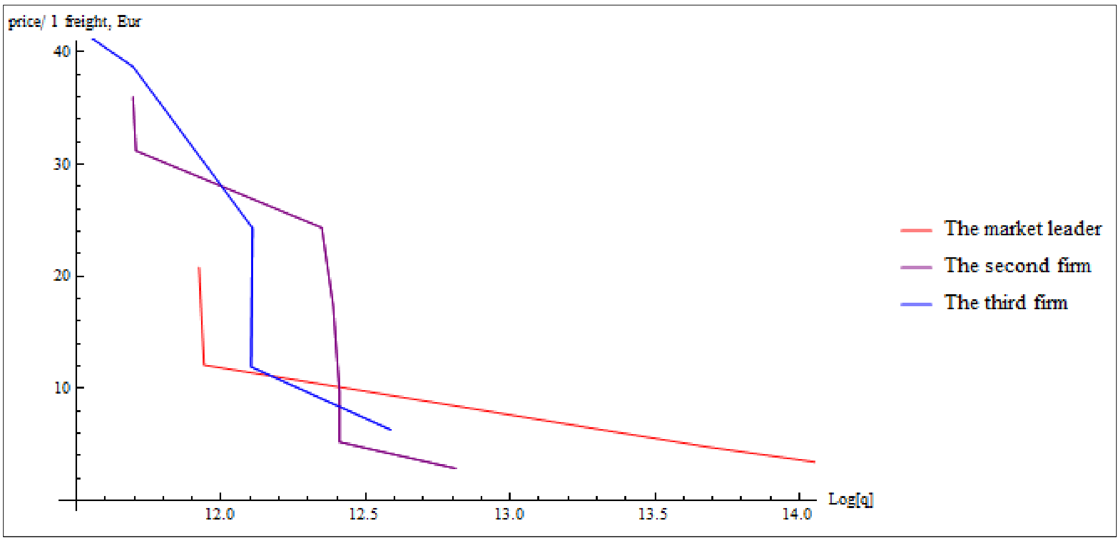


Figure 3 – Demand for logistics services

The logistics services are differentiated clearly. The demand for the market leader's services is more stable than for ones of rivals. It is well-known for all market participants that market leader has implemented IT applications that can be integrated with software of customers. The customers of the market leader treat this IT development as very significant added value. As well, it makes them addictive to the logistics services of the market leader. Therefore, he posses some market power that reflects in its margins as can be seen from Figure 4.

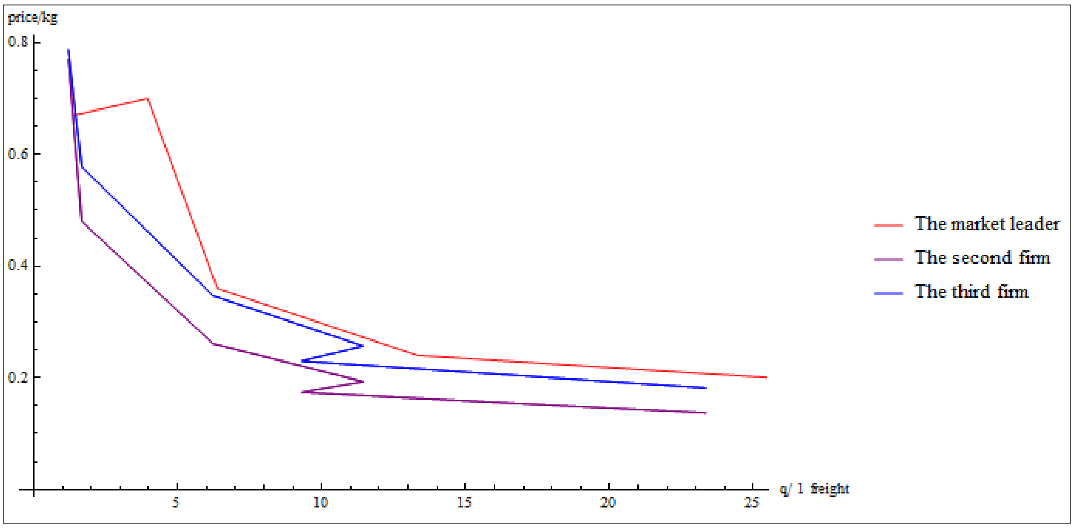


Figure 4 – Market prices

In small weight market leader takes significant market share and at the same time it apply higher markup.

Table 1 and Table 2 gives descriptive statistics for the different rivals.

Table 1 – Summary statistics

	mean	Sd/conf.level (0.9)	moda	Market share, %
The market leader	8.33554	7.41475/ 2.82793-12.0	12.5853	38.8148
The second firm	-4.9956	28.5288/ 12.793-44.265	11.4712	31.1852
The third firm	-9.8187	31.5868/ 12.34-50.83	8.4132	30

Table 2 – ANOVA

	DF (x, error, total)	SS (x, error, total)	MS (x, error)	F-statistic	P-value
The market leader	1, 4, 5	283.967, 56.3871, 340.354	283.967, 14.0968	20.1441	0.0109207
The second firm	1, 5, 6	813.212, 187.208, 1000.42	813.212, 37.4415	21.7195	0.00553
The third firm	1, 3, 4	1106.14, 121.6, 1227.74	1106.14, 40.5334	27.2897	0.0136444

The proposed model is suitable for practical application. The significantly lower the dispersion of demand of market leader reveals that customers give priority to market leader services in small size freights market. It is possible that such results depends on markets leader investments into its software integration with software of customers, which is different from other rivals. However, this advantage of market leader is not relevant in market in big size freights market. That entitles other two firms to charge much lower prices than market leader. The possible reason could be better adoption of other two firms of logistics in bigger size freights market.

5. CONCLUSSIONS

The study shows that logistics services are differentiated significantly due to investments into the quality of services. Higher quality helps to keep leading position and lower marginal costs for the leader of market.

The developed model from all of this class of models is different in system describing distinctive service differentiation with mathematical expressions: the greater the distance between the quality of services, the higher the market demand for differentiation factor γ. In addition, each service differentiation factor assessed individually in accordance with the level of quality – the service of higher quality, while its differentiation factor $\gamma(i)$ is greater. Different product differentiation factors $\gamma(i)$, depending on the distance between the service quality levels, determined by different demand curve slopes, while at the same time, the different market share and different market power of each firm.

There are three players in the market: the market leader has revenue mainly from freights of small weight, and the other two market players get some revenues from freights of small weight and higher revenues from freights, which have higher weights.

Thus, it is proposed vertically differentiated services demand determining methodology that literature was not given individual attention. The suggested model covers demand of logistics services firms' analysis.

This study has its own limitations. Therefore, further research could extend presented study to following directions: first, the diversity of logistics services in other European Union countries could be examined; second, the particularities of services' implementation of other logistics sub-sectors could be disclosed; third, the forecast of logistics market changes could be provided; also other directions could be specified.

6. REFERENCES

[1] Veldman, S.J., Buckman E.H.: *A Model on Container Port Competition: An Application for the West European Container Hub-Ports*, Maritime Economics & Logistics 5(2003), 3–22.

[2] Tsai, M-C., et al.: *Demand choice of high-tech industry for logistic service providers – an empirical case of an offshore science park in Taiwan*, Industrial Marketing Management, 36(5)(2007), 617–626.

[3] Chetty, R.: *Sufficient statistics for welfare analysis: A bridge between structural and reduced-form methods*, National Bureau of Economic Research, New York, 2008.

[4] Heckman, J.J.: *Building bridges between structural and program evaluation approaches to evaluating policy*, National Bureau of Economic Research, New York, 2010.

[5] Einav, L., Levin, J.D.: *Empirical industrial organization: A progress report*, National Bureau of Economic Research, New York, 2010.

[6] Train, K.E.: *Discrete choice methods with simulation*, Cambridge University press, Cambridge, 2009.

[7] McFadden, D.: *Conditional logit analysis of qualitative choice behavior*, University of California, Berkeley, 1974.

[8] Berry, S., et al.: *Automobile prices in market equilibrium*, Econometrica: Journal of the Econometric Society, 1995, 841–890.

[9] Aguirregabiria, V., Nevo, A.: *Recent developments in empirical IO: Dynamic demand and dynamic games,* Advances in Economics and Econometrics, 3(2013), 53–122.

INDEX OF AUTHORS

A

Alper, Doron....308
Alszer, Sara....119
de Araujo, Gabriel A. 299

B

Barreto O., Esther A. 12
Bargelis, Tautvydas....1
Bargelis, Algirdas....1
Belloso, Javier....292
Bielecki, Maciej....24
De Burgos J., Jerónimo....32
Burinskas, Arunas....381
Burinskiene, Aurelija....381

C

Canen, Alberto G....201
Cosic, Predrag....324

D

Dalbem, Marta C. 299
Dujak, Davor....283
Dukic, Goran....45

E

Ebner, Jonathan....332

F

Fae, Maria....186
Faulin, Javier....247, 292
Fialek, Pavol....195

G

García G., María J. 12, 32, 272
Gajewska, Teresa....56
Gdowska, Katarzyna....84, 109
Geraghty, John....332
Greenwood, Allen....65

H

Hanczak, Magdalena....24
Haurie, Alain....XIV
Hernández G., Gilberto J....12, 32, 272
Hernández R., José G. 12, 32, 272
Helo, Petri....221
Hill, Travis....65
Holt, Robbie....65

I

Izdebski, Mariusz....352

J

Jacyna-Gołda, Ilona....352
Jereb, Borut....136
Jerman, Boris....144
Jurasz, Jakub....74
Jurczyk, Krzysztof....84

K

Kaczmarczyk, Waldemar....XIII, 94
Kołodziej, Maksymilian....101
Korcyl, Antoni....109
Kramberger, Tomaž....136
Krawczyszyn, Paulina....216
Krystek, Jolanta....119
Książek, Roger....109
Kushnir-Berdugo, Vered....308
Kuźniar, Małgorzata....128, 364

L

Laskovsky, Vlastislav....195
Lerher, Tone....45, 136, 144
Lorenc, Augustyn....156, 168
Luić, Ljerka....231

M

Marszewska, Joanna R. 178
Mesarić, Josip....283
Mikulik, Jerzy....74, 84
Muniz, Daniel....186
Musil, Miroslav....195

N
Narcizo, Ramon Baptista 201

O
Opetuk, Tihomir............................. 45

P
Patlins, Pavels 209
Pejic, Vaska................................. 136
Pérez-Bernabeu, Elena.................. 247
Pesch, Erwin XI
Pocs, Remigijs.............................. 209
Potrč, Iztok.................................. 144

R
Rosi, Bojan................................... 136
Ryczyński, Jacek.......................... 216
Rymaszewska, Anna..................... 221

S
Saito, Minoru 371
Sanchez, Mercedes........................ 292
Saunders, Chase 65
Savic, Goran................................. 231
Sawik, Bartosz 239, 247, 292
Sawik, Tadeusz .... III, 255
Schwarz I., Lucía M...................... 272
Schwarz I., Trina M. 272
Schmidt, Benjamin S.G................ 264
Schmidt, Stefan 264
Schröder, Jürgen 315
Segetlija, Zdenko 283
Serrano-Hernandez, Adrian .. 247, 292
de Sinay, Maria C. F. 299
Sinay, Laura 299
Sinuany-Stern, Zilla ....XII, 308
Šraml, Matjaž............................... 144
Stach, Izabella 101
Strmčnik, Valerij.......................... 144
Szkoda, Maciej............................. 168

T
Tammela, Iara 201
Tomanek, Dagmar Piotr................ 315
Trstenjak, Maja 324

W
Wang, Jiayi 332
Wankowicz, Ewa 342
Wasiak, Mariusz 352
Wirz, Markus 315
Woźniak, Wojciech......................... 84
Wyraz, Elżbieta............... 56, 128, 364

Y
Yano, Yuji.................................... 371

Z
Zrnić, Nenad 144

ISBN 978-83-62079-06-3