International Conference on Industrial Logistics
11-13 June 2014, Bol on island Brač, Croatia

ICIL 2014
Conference Proceedings

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University of Vaasa, Finland
McLeod Institute of Simulation Sciences, California State University, Chico, USA
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Faculty of Transport and Traffic Science, Zagreb, Croatia
Łódź University of Technology, Faculty of Organization and Management, Department of Production Management and Logistics
Nanjing University of Information Science and Technology, School of Economics and Management, China
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ICIL 2014

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Editor’s foreword

It is with great pleasure that I present this publication, which contains the papers from the 12th International Conference on Industrial Logistics – ICIL 2014. The conference took place in Bol, island Brač, Croatia, from June 11th to June 13th 2014. It was hosted by the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb and by the International Centre for Innovation and Industrial Logistics.

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, Okinawa (Japan) 2001, Finland 2003, Uruguay 2005, Lithuania 2006, Israel 2008, again Brazil 2010 and Croatia 2012. Based on a successful conference in Croatia 2012, the ICIIL board decided to select again Croatia and the Faculty of Mechanical Engineering and Naval Architecture as a location and host of the ICIL conference in 2014.

The ICIL 2014 conference features a multidisciplinary program that includes original research results, developed concepts, ideas and real life case study examples as contributions to the fields of logistics and supply chain management, geared towards the understanding of and the solutions to the evolving logistics challenges in the world. Submissions for the conference came from 18 countries from 3 continents, confirming this conference as an international meeting place to share and exchange ideas and results, a place to make new contacts and open new possibilities.

On behalf of the organizing committee, let me wish to each one of you a successful meeting. I believe this meeting will facilitate the discussion and exchange of experiences and ideas, as well as enable contacts for further developments in the field of logistics in international contexts.

Assoc. Prof. Goran Đukić, PhD
University of Zagreb
Faculty of Mechanical Engineering and Naval Architecture
Zagreb, Croatia
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Bojan Jerbić

Dr. Bojan Jerbić is a Full Professor at the Faculty of Mechanical Engineering, University of Zagreb, the Department for Robotics and Automation of Manufacturing Systems. He teaches a number of courses in the field of automated systems planning, intelligent robotics and engineering computing. His scientific research is in the field of artificial intelligence and robotics, particularly in the development of cognitive control models for multi-agent robotic systems, the interaction of robots and humans and models of robotic consciousness. He has published more than hundred scientific papers, three textbooks and participated in various research and development projects. Currently he is the leader of interdisciplinary research project "Application of robots in neurosurgery – RONNA" that will soon be verified by a clinical application. Thanks to research projects conducted in collaboration with industry he has developed one of the most advanced laboratories for applied robotics in Europe. He is a member of the editorial boards of the journal “International Journal of Simulation Modeling” and “Transactions of FAMENA”. Also, he is a member of the Croatian Society for Robotics, Secretary of the Department of Cybernetics of the Croatian Academy of Engineering and a member of the Scientific Council for the Development of the Croatian Academy of Sciences and Arts.

New Robotic Challenges

Why are robots so impressive in the factory, but so incompetent in human environment? The most sophisticated robot today would be unable to get you piece of bread! How to get to the new robotic era from our futuristic visions? If we really want to.

We need new robotic paradigms. Intelligent Robot should be a harmony that comes from the permeation of physical and virtual machines and environment concepts. Once the mind and the body were separated according to the Descartes Dualism, philosophers found it necessary to find a way to reconnect these two aspects, because interaction between Descartes mental and physical concepts is essential for human existence. Besides, if roboticists want to create really useful and intelligent robots they have to think about them within the background of different cultures and concepts.
Wilfried Sihn

Wilfried Sihn, Univ.-Prof. Prof. eh. Dr.-Ing. Dr. h.c. Dipl.-Wirtsch.-Ing., was born in Pforzheim, Germany, in 1955. From 1976 to 1982 he studied Business Engineering at the TH Karlsruhe. He earned his doctorate from the University of Stuttgart in 1992. In 1982 he started working at the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) in Stuttgart, first as a Research Fellow, then as a Group Manager, Head of Department and Division Director, and from 2000 as Deputy Director.

In September 2004 he joined the Vienna University of Technology to work as Professor for Industrial and Systems Engineering at the Institute of Management Science and from March 2009 to December 2010 he was head of this institute.

Since December 2008 he is Director of Fraunhofer Austria manages the Division Production and Logistics Management in Vienna.

In May 2007 he earned a honorary doctorate (Dr.h.c.) of the University in Skopje/Macedonia. In November 2009 he earned a honorary professor (Prof. eh.) of the University “Politehnica” of Bucharest/Romana.

Professor Sihn has been active in the field of applied research and consulting services for more than 25 years now. His areas of expertise include production management, corporate organization, enterprise logistics, factory planning, order management and business process reengineering. In addition, he led projects in the fields of business structuring and business controlling and he was instrumental in developing such concepts as the Fractal Company.

Prof. Dr. Wilfried Sihn is vice president of the International Society of Agile Manufacturing and International Editor of the journal Agility and Global Competition, as well as Guest Editor of the International Journal of Technology Management (IJTM). He holds lectures on the above-mentioned topics at national and international conferences. His more than 200 publications also include several books, making him an active player in scientific and practice-related discussions.

He directs the Austrian Scientific Plattform for Logistics (WissLog) and he is board and vice president of the Austrian Logistics Association (BVL). Furthermore he is member of multiple boards of directors and boards of administration as well as member of the European Academy for Industrial Management (AIM), the scientific society for working organisation and company organisation (HAB) as well as board member of the International Federation of Production Research (IFPR).

In February 2006, Prof. Sihn was invited to become a member of the International Academy for Production Engineering (CIRP). In October 2010 he was invited as board in the German Chamber of Commerce (DHK) in Vienna and since March 2011 he is member of the American Chamber of Commerce in Austria (AMCHAM). Since May 2011 Prof. Sihn is vice president of the Initiative on European Learning Factories.

Industry 4.0: Opportunities and Potentials

Industry 4.0 represents a new level of organization and control of the product value chain along the whole life cycle. The central basis is the availability of all relevant information in real time through networking of all objects involved in the value stream and the ability of the data to derive the optimal value stream at each time point. By connecting people, objects, and systems dynamic, real-time-optimized and self-organizing value-added networks can be realized in an optimized way according to different criteria such as cost, availability and consumption of resources. It involves seizing the opportunities to generate innovative and holistic solutions rather than selling existing island solutions under a new cover. In the presentation the relevance of the theme, potentials and application examples, as well as a possible way to implement industry 4.0 in practice will be highlighted.

**Keywords:** industry 4.0, cyber-physical-system (CPS), cyber-physical-production-system (CPPS), product value chain and life cycle, innovation and technology road mapping
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Conference Papers
EVALUATION OF LOGISTICS TECHNOLOGIES AND SERVICES IN TERMS OF EFFICIENCY AND SUSTAINABILITY

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Abstract
Rapidly growing population and the increasing demand for quality of life in emerging and developing countries are just two trends which will cause major challenges in future. Sustainable actions and a more efficient use of resources will increasingly be a key factor in growth and employment policies. In this context, the field of logistics offers considerable potential for optimization in terms of efficiency and resource conservation. This paper shows which requirements are imposed on procedures or methods to measure the efficiency based on greenhouse gas emissions (GHG) of logistics technologies and services and gives an evaluation of existing standards and guidelines.

Keywords: efficiency in logistics, sustainable logistics, efficiency and sustainability evaluation

1. INTRODUCTION
Around 22% of global greenhouse gas (GHG) emissions are caused by the transport sector [1]. Although the global GHG emissions in the period 1990-2005 in the UNFCCC countries decreased by about 2%, it grew in the same period in the transport sector by 43% to 3.47 billion tonnes [2]. As a key driver in this context, especially a sharp increase in transport services of freight traffic is identified. The implementation of modern logistics concepts such as, for example, just-in-time, but also the pursuit of outsourcing strategies in production companies or developments in ecommerce are driving reasons for this development [3].

In order to reduce the emission of greenhouse gases and subsequently the effects on climate change, different approaches that can be technological, operative, organizational and political in nature exists [4]. The derived concrete actions such as the implementation of a more efficient truck fleet or a new inventory and warehouse strategy to avoid transports, thus requires as part of the investment decision as well as economic consideration of ecological factors. However, standardized measurement methods for determining the efficiency of logistical activities within the meaning of GHG emissions are missing. Specifically related to the logistics, no internationally accepted standards are available. It must therefore be proved, what implications have existing standards and guidelines on logistics.

2. CLIMATE CHANGE AND THE FIELD OF LOGISTICS
The term climate change is generally understood to be caused by humans (=“antropogenic”). It is assumed that emissions of greenhouse gases increase the annual average temperatures ("Global Warming"), which is to be expected, subsequently, with the increase in extreme weather events. The historical development shows that there were always natural fluctuations of the climate, but the currently observed increases are not due to this, but have human influence.

The main cause of climate change, especially the use of fossil energy, the transport, agricultural use and the change of land use shall apply.

If the overall EU 27 (European Union) energy consumption is analyzed, it can be seen that the largest proportion, nearly one-third, is caused by the transport sector within EU, too. This compares with an share of emissions of about 20%. As mentioned above the sector transport in 2010 had a share of the global
greenhouse gas emissions by 22%. Out of that figure logistics caused about 64% of it, which corresponds to a share of the total greenhouse gas emissions by more than 14% [5].

Within the transport sector, emissions can be divided on the individual transport modes, which are attributable to 72% of the road transport. The ship and the civil aviation forms number two and three of the largest emitters of greenhouse gases with well over 10%. The train with about 1% of sectoral emissions is represented comparatively low due to the high degree of electrification.

These developments presented show that transports and, subsequently, the field of logistics has a major lever in the reduction of greenhouse gas emissions. The logistics may thus be a valuable contribution to the achievement of environmental and climate change objectives.

However, to measure efficiency improvements, standardized and internationally accepted standards are necessary. Thus, the measurement and calculation of greenhouse gas emissions, but also the assessment would unify this.

3. REQUIREMENTS FOR EVALUATION METHODS

On closer contemplation can be stated that there are both general and logistics specific requirements, which are placed on a standardized method for the evaluation of logistics technologies and services.

The key objective is to determine a comparability and evaluation of the validity of different calculation results. This requires in addition to standardize methodologies (e.g. LCA, Life Cycle Assessment) standardized calculation methods and approaches. For example, nowadays two companies can get incomparable results using the LCA method, since they do not use the same method of calculation.

3.1 General requirements

For methods to evaluate the efficiency and sustainability general requirements can be defined, which are valid independent of the field of application.

- **Flexibility**: The method should not only have a single focus, but can be used widely. The process steps of a possibly underlying model should be defined as precisely that comparability between studies is possible, but the flexibility is not restricted.

- **Environmental Exposure**: The Scope of the assessment method should be flexible so that not only effects directly associated with the product or services are shown, but also indirectly related effects (e.g. economic and / or social components).

- **Transparency**: The validity of an assessment method for comprehensive and holistic assessment of efficiency is to make the complexity manageable by a corresponding transparency. The method shall ensure an appropriate calculation and analysis of the data.

- **Holistic approach**: To take all product- and service-related interdependencies into account, a holistic approach is necessary. The EN ISO 14040, for example, defines such type of approach in conjunction with the LCA as "... all aspects of the natural environment, human health and resources."

- **Consistency**: The calculated results must be consistent, i.e. logical and coherent.

- **Accuracy**: Systematic Errors and uncertainties during the calculations or in the calculation results should be minimized and thus lead to a maximum accuracy.

This non-exhaustive list shows the versatility of a valuation method, with regard to the possible process complexity in logistics.
3.2 Specific requirements for the field of logistics

To determine the specific requirements of an evaluation method for the logistics sector, it is necessary that at the beginning present challenges are defined and analyzed.

In the calculation of carbon footprints for logistics technologies and services has a variety of challenges and problems that can be mainly summarized in the following key points [6]:

- **Limited standardization** and the lack of uniform standards and calculation methods
- **Problems of data collection**, both in their own companies, but also in particular for subcontractors
- **Large number of possible reference and determinants** complicate the manufacture of transparency and comparability of GHG balances of different companies.

Probably the biggest of these challenges is the acquisition of appropriate data. Most are expected due to the difficulties associated with the detection of assumptions or averages. This leads thereafter to the fact that the carbon footprints of different entities, regardless of whether they may also have a similar product or service portfolio that is not comparable.

Based on the stated challenges, the flexibility must be cited as a central logistics specific requirement. The evaluation method must be flexible so that the diverse processes of logistics can be represented.

4. STATUS QUO IN EVALUATING THE EFFICIENCY AND SUSTAINABILITY

4.1 Politics and the economy in general perspective

At a political level, there are a number of initiatives intended to govern energy policy and the current and future use of energy, raw materials and other resources in the European Union. This shows that there are many valuable approaches to the field of sustainability.

The following list contains the most important strategic documents of the European Union:

- **The renewed EU Sustainable Development Strategy**: The Treaty of Amsterdam, which came into force in 1999, anchored sustainable development as a fundamental objective of the European Union. The EU SDS (EU Sustainable Development Strategy) was adopted in 2001 and supplemented the Lisbon strategy for growth and employment to the environmental dimension.

- **Energy Efficiency Plan 2011 of the EU**: The in 2011 adopted Commission's Energy Efficiency Plan is part of the EU's 2020 strategy and will contribute significantly to achieve the objective of reducing emissions by 2020 by 20%.

  In the energy efficiency plan are as areas with particularly high potential to increase energy efficiency and energy savings, the following sectors seen:
  - Building
  - Traffic
  - Industry

  Other key objectives contained in the Energy Efficiency Plan are to improve the energy independence and security of supply. Through the implementation of measures to large savings can be realized.

- **"Resource efficient Europe" - Flagship initiative under the Europe 2020 strategy**: This initiative is the transition to a low carbon economy supporting the effective use of resources and sustainable growth. It gives a framework for action to support strategic programs in the areas of climate protection, energy, transport, industry, raw materials, agriculture, etc. and attempts to mainstream resource efficiency accordingly.
The aim of the flagship initiative is the establishment of resource efficiency in the policy as a basis for ensuring long-term strategies of energy, climate, research and innovation, transport, agriculture, fisheries and environmental policy.

- **Energy Roadmap 2050**: The Energy Roadmap is the long-term framework for action on European energy policy and its medium-term strategic objectives, including an action plan for energy efficiency and the Energy Strategy 2020. There are pointed sectoral targets, can be as energy security and competitiveness through a "low-carbon economy" increased or improved. The Energy Roadmap 2050 is the demonstration of the feasibility of a clean energy system and existing opportunities and challenges.

- **White Paper "Adapting to climate change"**: Towards a European framework for action, the White Paper of the Commission of the European Communities sets out a framework for action, such as the European Member States to prepare for the impacts of climate change. It is the EU's resilience to climate change will be improved so that its effects are manageable.

This overview of strategic documents of the European Union shows how far-reaching the considerations in the field of sustainability and efficiency are. They suggest that the requirements of the economy on the part of policy will be tightened accordingly. The challenge for policy makers is an appropriate implementation of the strategies and projects described above. Care should be taken to an appropriate stringency, without the pronunciation of coercive measures or regulations. A "healthy" growth in the field of sustainability can be supported only this way.

As part of the sustainability strategy, the Kyoto Protocol is to mention. There is no EU-internal definition, but at the end of 2011 it was ratified by 193 States and the European Union. Established in the year 1997, from the catalog of measures of the Climate Convention in Rio de Janeiro resulting 1992 Kyoto Protocol was made compulsory by a quantification of the emission reduction targets. The protocol contains two commitment periods; the second was adopted in December 2012:

- **Commitment Period 1**: reduction of the six-damaging greenhouse gases in the period 2008 to 2012 compared to the base value of 1990 by an average of 5.2%.

- **Commitment Period 2**: reduction of greenhouse gases by 2020 compared to the underlying in 1990 by 20%.

  For the commitment period 2, in addition, a seventh greenhouse gas (nitrogen trifluoride NF3) was recorded in the minutes.

### 4.2 Existing Standards and guidelines and their application to the field of logistics

There are many norms and guidelines relating to the issues of energy efficiency and sustainability, but their application in the field logistics is possible limited or nearly not possible.

After a detailed evaluation, which cannot be part of this paper, standards have been identified that can partially circumvent very well with the complexity in logistics. The table shows the standards with their different dimensions. The stated standards are differentiated according to their system boundaries.
After a detailed evaluation, which cannot be part of this paper, standards have been identified that can application in the field logistics is possible limited or nearly not possible.

This overview of strategic documents of the European Union shows how far-reaching the considerations in As part of the sustainability strategy, the Kyoto Protocol is to mention. There is no EU-internal definition, supported only this way. A pronunciation of coercive measures or regulations. A “healthy” growth in the field of sustainability can be the strategies and projects described above. Care should be taken to an appropriate stringency, without the policy will be tightened accordingly. The challenge for policy makers is an appropriate implementation of the field of sustainability and efficiency are. They suggest that the requirements of the economy on the part of commitment periods; the second was adopted in December 2012:

- Committed to a quantification of the emission reduction targets. The protocol contains two from the catalog of measures of the Climate Convention in Rio de Janeiro resulting 1992 Kyoto Protocol was recorded in the minutes.
- White Paper “Adapting to climate change existing opportunities and challenges.
- The Energy Roadmap 2050 is the demonstration of the feasibility of a clean energy system and efficiency and the Energy Strategy 2020. There are pointed sectoral targets, can be as energy security

Commitment Period 2:
- GHG Protocol: The GHG Protocol is designed similar to the EN ISO 14064 essentially aimed at the corporate level. The Project Accounting Protocol also allows the examination of project-specific issues (e.g. acquisition of a new forklift truck fleet).
- EN ISO 14040ff: The EN ISO 14040 identifies the principles and framework of the LCA, which is a sign that the LCA can be used in principle very far-reaching. These standards define no specific survey methods or techniques, and therefore no limit in the use for logistics is identifiable.
- EN ISO 14067: The EN ISO 14067 allows the viewing of the product carbon footprint over the whole life cycle of a product. An aptitude for evaluating logistics technologies and services is therefore given.
- EN 16258: The EN 16258 is used primarily for those organizations that perform a quantification of transport services, such as freight and passenger transport service providers or organizers of transportation services (e.g. freight forwarders). In addition to inter-and intra-company transport and the evaluation of internal transport (intra-logistics) in terms of their energy consumption and the resulting emissions is possible with this methodology. Annex A of EN 16258 in addition also conversion factors for electricity are described and named, so electrically powered vehicles, especially in the field of traction, can be taken into account. Handling- and manipulation equipment

<table>
<thead>
<tr>
<th>Standards and Guidelines</th>
<th>Corporate Carbon Footprint</th>
<th>Product Carbon Footprint</th>
<th>Climate Impact of Transport Services</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EN ISO 14064, GHG Protocol</td>
<td>EN ISO 14040ff, EN ISO 14067, GHG Protocol, PAS 2050</td>
<td>EN 16258 (draft)</td>
</tr>
<tr>
<td>System Boundaries</td>
<td>Subcontractor voluntarily; activities of your own company mandatory</td>
<td>Entire value chain, whether internal or external processes</td>
<td>Total transport chain, regardless of whether their own vehicles or those of sub-contractors</td>
</tr>
<tr>
<td>Environmental Parameters</td>
<td>all greenhouse gases as CO2 equivalents</td>
<td>all greenhouse gases as CO2 equivalents</td>
<td>all greenhouse gases as CO2 equivalents + energy consumption</td>
</tr>
</tbody>
</table>

Table 1 – Comparison of standards and guidelines [7]

- **EN ISO 14064:** The standard series EN ISO 14064 refers compared to LCA not to products or services, but on organizations and their greenhouse gas emissions. The implications on the logistics are therefore to look at infrastructural level, such as the construction of a new warehouse using materials for energy-efficient operations.
- **GHG Protocol:** The GHG Protocol is designed similar to the EN ISO 14064 essentially aimed at the corporate level. The Project Accounting Protocol also allows the examination of project-specific issues (e.g. acquisition of a new forklift truck fleet).
- **EN ISO 14040ff:** The EN ISO 14040 identifies the principles and framework of the LCA, which is a sign that the LCA can be used in principle very far-reaching. These standards define no specific survey methods or techniques, and therefore no limit in the use for logistics is identifiable.
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5. CONCLUSIONS

The starting point of this paper was the fact that the issues of sustainability and efficiency gain increasing importance. A rapidly growing population in emerging and developing countries and their increasing desire for prosperity coupled with rapid developments in the fields of industry, transport, etc. in the European and American countries will in future make the distribution of natural resources to a problem. Especially with respect to future generations who will probably put in a continuation of the current consumption patterns with even greater problems. With the consumption of natural resources, accompanied of climate change and the associated climatic consequences are becoming increasingly problematic. A countersteering on the part of the legislation, for slowing or halting of climate change, is a prerequisite for the preservation of our environment creating a sustainable management of natural resources.

It is shown that the emission share of logistics in the global environment is around 14% and underlined the associated leverage this industry to reduce greenhouse gas emissions. Further requirements were identified and the status quo of evaluation of logistics technologies and services.
With regard to the requirements of a method it was stated that especially the flexibility regarding the applicability of standardized assessment procedures play an important role. The limited standardization as well as the large number of possible reference and destination sizes is currently in the logistics, the most significant challenges.

Existing standards have a high degree of flexibility, but provide no standardized calculation models. This leads to a non-comparability of emission calculations, even if companies offer similar products or services.

The challenge of efficiency evaluation of logistics technologies and services does not exist in the calculation of GHG emissions per se, but in the creation of international guidelines and manuals for the calculation to make GHG balances comparable.

This lack of comparability hast to be analysed and verified in further studies.

6. REFERENCES


SELECTION OF WAREHOUSE PLACE

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Abstract
In companies’ economics science, where are a lot of ways how to select a warehouse’s place. For such mathematical models, analytic techniques, linear programming techniques, and simulation are used. Some of the methods involve demand factor into location analysis, but overall objective is to minimize the total costs.

The empirical research is given to retailer WHs selection problem. Multiple methods are used to deliver the best results for predicting warehouse place.

The research ends with suggestions for Globus retail chain where optional warehouse places are formulated.

Keywords: warehouse’ place, retail chain, vector distance

1. INTRODUCTION

Traditional mathematical models used for the selection of warehouse place often don't consider actual transportation distance. The distance between two points is often assumed as the straight line in models, so the analytical result usually cannot be precise. One of such mathematical models is the traditional P-median selecting location model of logistics. A radius formulation is applied very successfully to solve the p-median problem.

Four different approaches are presented herein. The first one continuous model (Steiner – Weber) helps to specify unlimited potential number of warehousing places. The second one discrete model helps to find also warehouse location with minimal costs. The third one Break-Even-analysis is applicable to find that break-even point which would be the net case for warehouse place selection. The fourth one approach included in the topic of warehouse place selection, is the optimal amount of warehouse. The approach is used in the situations when warehousing costs are lower than economized transportation costs.

The paper takes Globus chain example and adopts the geographical information system (GIS) attribute information to find warehouse place; later on compares results between vector distance and items transportation distance. The paper finishes with a simple simulation exercise. The objective is to find the best location of supply point (the one that minimizes total transportation costs). It is assumed that the transportation costs are related to the route length from the warehouse to the demand points; other transport conditions are not considered.

Computational results on the ranking procedure are presented, and a problem involving one warehouse and fifty seven hypermarkets is analyzed.

2. LITERATURE ANALYSIS

Last macro view is the combination of theories of economic geography specialists. Many of these theories are based on distance and costs assessment. Experts of economic geography seeking to decide on the location include also the demand and profitability factors, while emphasizing the importance of reducing the costs.

For this reason, it is instructive to examine the factors of locational analysis from its origins in analytical geometry through the work of the economic geographers to the current emphasis on the systems approach to distribution. The warehouse location selection need consider main factors: the natural environment factor including meteorology, geology, hydrology, topography, and so on; the business environment factor including demand layout, logistical expenses, and so on; the infrastructure condition including traffic, public...
The five factors including terrain, area of the warehouse, rent, distance, and land type are selected by Huifeng et al. 2008.

The location of economic facilities has existed as a problem for some considerable time, yet its emergence as an integral part of total distribution planning seems quite recent. The selection of warehouse location is very complex question. The development of techniques to solve particular, well defined problems has resulted in a wide range of algorithms, heuristics, and programs (Westwood, 1974): mathematical models; analytic techniques; linear programming techniques, and simulation.

Steiner – Weber model. Main point is that there is unlimited potential number where warehouses could be placed. Every point of realization area is a possible allocation place. For searching warehouse place, transportation costs are minimized according the following formula:

$$T = c \sum_{j=1}^{n} b_j \sqrt{(x - u_j)^2 + (y - v_j)^2}$$

(1)

herein: $T$ is Transportation costs, $j$ – customer (store), $n$ – number of stores, $b$ – minimal transportation costs, $c$ – costs per transport unit, $x, u, y, v$ – location points (as specified in Figure 1).

**Figure 1** – Searching location for a warehouse $(x, y)$

Discrete model is similar to Steiner – Weber model. Discrete model is mainly used for the same goal as Steiner – Weber model: to find a warehouse location with minimal costs (transportation and fixed costs).

IBM developed solution for searching retail warehouse location, which is a typical discrete optimization problem. The number of locations for warehouses is considered by enterprise. Each possible warehouse has a fixed operating costs and a maximum capacity specifying how many stores it can support. In addition, each store must be supplied by single warehouse and the costs of supply to store depend on the warehouse selected. The model consists of choosing where to build warehouses and which warehouse to assign to each store in order to minimize the total costs, i.e., the sum of the fixed and transportation costs (IBM, 2014).

Break-Even-Analysis. The main goal is to find that Break-Even point which would be the nested case for warehouse place selection. Because there might be cases when outsourcing arises – it is a situation where the storage location is not economical. Break-Even-Analysis is based on simplified costs’ consideration: linear, static cost’s function, fixed costs specific for a storage location $f_j$, and variable costs specific for a storage location. Break – Even – Analysis is showed in Figure 2:

**Figure 2** – Break-Even point
Searching the optimal amount of warehouses. Number of warehouses also includes in the topic of warehouse place selection. An additional warehouse settlement is an advantage only in that situation when warehousing costs are lower than economized transportation costs. In the literature to the problem of warehouses amount is looked only in the way of freightage costs dynamic. This dependence is shown in Figure 3:

![Figure 3 – The number of warehouses (WH’s)](image)

Herein, transport costs are defined as transportation costs from warehouses to stores and vice versa. The red line in the graph shows the optimal number of warehouses.

Demand affects via costs not only the number of warehouses but also their size. The need to have more space for storage of larger volumes exists. For the decision of warehouse size not only for the storage and transportation costs are important, but also in such financial factors as loss of missed sales, investment into stocks.

The term “selection” means the choice among couple or multiple alternatives. The classical algorithm includes the center-of-gravity approach, the Uncapacitated and capacitated facility location problem (UFLP and CFLP) model, the Baumol-Wolfe methods, and the P-median selecting location model, in the warehouse location selection. One of the assumptions of the Capacitated Facility Location Problem (CFLP) is that demand is known and fixed. But in practice demand is fluctuating.

Facility Location Problems (FLP) deserved the special place in location selection literature in the second half of the last century. The FLP derives its name from the analogy to decision problems concerning the location of facilities (e.g. factories, warehouses, etc.) so as to minimize the total costs of serving customers (e.g. depots, retail outlets, clients). FLP considers situations in which a commodity is supplied from a single or multiple plants, selected from a set of potential location sites to serve demand points (Silva et al. 2007).

In the literature, UFLP and CFLP models are divided into three categories: Models with non-linear storage costs and linear transportation costs, models with linear storage costs and non-linear transportation costs, and models with non-linear storage costs and non-linear transportation costs.

First type of models has been developed for uncapacitated and capacitated sites. Some of authors used a continuous version of the problem, where warehouses can be located anywhere and are not restricted to a set of predefined potential locations. They solved the problem with an adaptive location-allocation. Kelly et al. (1982) modeled the problem as a transportation problem and solved this problem iteratively using marginal costs that depend on the current volume allocated to each site. Later on, iterative linearization techniques have been used for a multi-product problem and a multi-period problem. A stochastic model that also includes inventory costs was also analyzed in the literature (Baumgartner et al. 2010).

In the second type of models warehousing costs are treated quite differently. In a number of models, warehousing costs are excluded. The authors analyze the design of multi-products; consider a location model with comprehensive costs functions, for example, taking into account full truckload discounts and various...
transportation modes. They solve the problem with variable neighborhood search algorithms. A model developed by Lin et al. (2006) included fixed but no variable warehousing costs have been introduced. They determined transportation costs based on total flow and assumed that they are independent of orders sizes. Gumus et al. (2002) suggested cross-docking model that combines full truckloads. Other authors optimized transport frequencies.

Third type of models was first analyzed in 1958 by Baumol et al. The proposed model did not include inventory costs or replenishment frequencies. Similar models involve minimum costs network flow algorithm. Some authors expand this model to a stochastic environment with safety stock.

The literature review shows that existing research has addressed subsets of the factors that are relevant for the selection of warehouse place.

In this paper author model each of the demand points as an independent queue. A geometrical relationship among demand points is constructed.

3. RESEARCH

Globus is retail chain located in Germany. First Globus store was opened in 1970. In 2012, chain had 45 and these days there are 57 hypermarkets (as shown in Fig. 1). Retail chain has single warehouse located in Bingen, which serves stores around Germany. The warehouse is placed in Baden-Württemberg region and serves 57 Globus hypermarkets by unique warehouse.

![Figure 4 – Location of Globus grocery stores in Germany (Globus, 2014)](image)

Since the enterprise has warehouse, the author assumes that fixed warehousing costs will not be higher for a new warehouse. In this particular case, single costs for a change of warehouse will be appearing and could be included into the model as transportation costs. The main part of research on the optimization of transportation costs is carried out in two directions. The aim of the research is to find a better solution for Globus chain warehouse location. The first direction involves vector distance between two points, representing one of stores and warehouse. For such analysis Wolfram Mathematica package is used seeking to receive the vector distance (geodistance) in meters between latitude-longitude positions on the Earth:

\[
D_j = GeoDis[\{lat_x, long_x\}, \{lat_y, long_y\}]
\]

herein: \(D\) is the straight distance between supply point and store \(j\), \(lat\) – latitude, \(long\) – longitude.

In this phase top ten candidate warehouse places are selected.

Second direction is chosen to confirm or decline previous research results. Route network is used to replace the straight distance.

The sum of the shortest distances from the warehouse \(i\) to all the all demand points \(j\), \(L_i\) is computed as following:

\[
L_i = \sum_{j=1}^{n} d_j
\]

Among it, \(d_j\) is the shortest distance from the revised warehouse \(i\) to the demand point \(j\).
In the final stage ranking is applied. The greater the value of $L_i$, the lower is rank. According rank results $L_1 < L_2 < L_3$, enterprise should choose the place for warehouse, which appeared in the first place. The results are compared with $L_6$ which calculated to retail chain warehouse located in Bingen (Eyefortransport, 2012). Linearized transportation costs are presented at the end of this stage. Herein, transportation costs are compared to present distance from the costs for the best candidate warehouse.

For first tests, 16 places located in the middle of Germany are selected: Bebra, Butzbach, Darmstadt, Dillenburg, Frankfurt, Fulda, Giessen, Haiger, Herborn, Idstein, Koblenz, Mainz, Marburg, Meiningen, Weisbaden, and Wetzlar. The location of Bingen is also revised. For the second step, places are ranked seeking to clarify top 10 locations. The research results confirmed that the best vector distance results are received for Giessen, Butzbach, Wetzlar, Marburg, Dillenburg, Herborn, Haiger, Frankfurt, Fulda, and Idstein (locations are ranked in priority sequence).

During the second phase, it is clarified that, from transportation distance point of view, the best option for warehouse have to be selected from these top 5 locations: warehouse in Frankfurt (7.44 % kilometer savings compared with current Globus warehouse location in Bingen), Darmstadt (6.48 %), Giessen (5.07 %), Fulda (5.02 %), and Butzbach (4.01 %).

### Table 1 – Location of a warehouse

<table>
<thead>
<tr>
<th>$i$</th>
<th>Place</th>
<th>Latitude</th>
<th>Longitude</th>
<th>$L_i$ km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frankfurt</td>
<td>50.110922</td>
<td>8.682127</td>
<td>15 538</td>
</tr>
<tr>
<td>2</td>
<td>Darmstadt</td>
<td>49.877648</td>
<td>8.651762</td>
<td>15 699</td>
</tr>
<tr>
<td>3</td>
<td>Giessen</td>
<td>50.587142</td>
<td>8.690926</td>
<td>15 937</td>
</tr>
<tr>
<td>4</td>
<td>Fulda</td>
<td>50.55581</td>
<td>9.680845</td>
<td>15 945</td>
</tr>
<tr>
<td>5</td>
<td>Butzbach</td>
<td>50.435036</td>
<td>8.668842</td>
<td>16 114</td>
</tr>
<tr>
<td>6</td>
<td>Bingen (current place)</td>
<td>49.96674</td>
<td>7.904596</td>
<td>16 787</td>
</tr>
</tbody>
</table>

Source: created by author

The results of the research show that current Globus warehouse place is determined by historical or political motives. But nowadays due to retail chain expansion and especially new plans to open 2 stores in Erfurt (Linderbach and Mittelhausen), which is nearest to the geographical center of Germany, the movement of warehouse to another place shows significant savings in transport costs.

The research results also show that distance, which is calculated by road network, is realer than the straight line.

The volume per truck depends on the chosen transportation frequency. Since multi-products are usually shipped in separate trailers or compartments but on a single truck, the transportation costs $T(q)$ on the total volume of all products $q$ could be calculated as presented in Formula 4.

$$T(q) = c \cdot q \cdot L_i$$

Parts of the transportation costs stated before are characterized by piecewise linear costs function. Such function was first proposed by Balakrishnan and Graves (1989). Since the task is uncapacitated when $B$ denotes the transportation quantities $m^3$ at which breakpoints for fixed transportation costs occur, where $i$ refer to the transportation costs level and consecutively numbers for the breakpoints; where $0 < B_1 < ... < B_n$ denote the breakpoints between the segments (see Figure 5).
Therefore, it is important to evaluate economies of scale.

4. SUGGESTIONS

Finally, for the selection of location the method proposed by R. Kuvykaite (1997) can be used. This method is called convergence method and has such steps:

- First step, from all candidate warehouse places enterprise have to eliminate those locations, which are not attractive economically;
- Second step, from places, which are left after previous elimination, additional candidate warehouse locations are eliminated, mainly, those where the enterprise has no available infrastructure or labor resources.

Malhotra et al. (2009) offer to take into account also the role of different distance factors (geographic distance, cultural distance, economic distance, etc.) on firms behavior when place is selected in the foreign market. Also, indicators, which are characterizing economic development and political stability of foreign market, could be used. On the other hand, the decision of multinational enterprises on concrete place could be influenced by knowledge about cultural and institutional environment.

Mentioned authors provide also empirical support about such behavior by multinational and national enterprises. Results show that national enterprises usually select from the closest neighbor places.

5. CONCLUSIONS

The location goal of most distribution centers is to select a site that offers the lowest possible transportation costs with the easiest access to the greatest number of stores.

There are simple ways for solving the problems of warehouse place selection. Most popular examples of location problem solving are continuous model (Steiner – Weber), discrete model and break – even – analysis. Also, UFLP and CFLP are used for the optimization of transportation costs. In the literature, FLP is used to present costs dynamics.

Number of warehouses is also very important factor which should be looked at while searching the location. Geographic location often is still a key factor. From the example of Globus, it is clear that the geographical location is a very big advantage for that company. Moreover, this is a significant advantage to stores in terms of fast delivery and costs savings.

To conclude, a warehouse location is a high-level strategic decision problem which should be measured in very appropriate calculations, know-how, expectations, strategies and lots of other important factors. The research has its limitations. So, future studies should expand this research to such directions: optimization of product mix, locations, material flows, and transport frequencies in an environment with economies of scale in transport, and warehousing.
6. APPENDIX


7. REFERENCES


TRACKING AND TRACING APPLICATIONS IN PROJECT-BASED SUPPLY CHAINS

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Abstract

A tracking system is a computer system based around a so called checkpoint network: when a tracked item arrives at a collection point in the supply chain the status of the item is registered and an update message are sent to a tracking database. New technological advances related to RFID, bar codes, GPS-trackers have enabled building a real-time view on supply chain. This paper analyses some of the technologies and proposes a framework that could be used in project-based industries including global suppliers and global deliveries.

Keywords: real-time tracking, supply chain management, project business.

1. INTRODUCTION

According to Frohlich & Westbrook [1] a well-designed logistics integration is based on the coordinated flow of information and materials from suppliers. Tracking systems that link information systems and the material flow are essential in this integration [2]. Since their development, tracking systems have generated transparency in the supply chain, raising the operational efficiency of the chain (see for instance Stefansson and Tilanus [3]; Loebbecke and Powell [4]). New technology related to tracker devices, information technology and global telecommunication systems have enabled new applications.

Currently, state of the art tracking and tracing systems are used by global courier companies, such as DHL, FedEx and UPS. Common for these systems is that a single company controls the entire material flow. Manufacturing companies have similar needs to track and trace both inbound and outbound logistics. However, they are not able to rely on single transportation company and do not own all parts of the supply chain. Especially, companies operating in project business environment have specific needs on managing network of suppliers, varying locations and large variety of deliveries (Sandhu and Helo [5]).

These manufacturing companies operating in project business need to have a solution for multi-site, multi-vendor, multi-transport company which is able to produce a transparent and up-to-date picture of each shipments. This paper aims to analyse the specific needs for developing such system and outline technical features for real-time tracking in global supply chains.

2. REVIEW ON TRACKING SYSTEMS

A tracking system is most often based around a so called checkpoint network: when a tracked item arrives at natural collection point in the supply chain (a checkpoint) the status of the item is registered and an update message is sent to a tracking database (Kärkkäinen, Holmström, Främling and Artto [6]). Usually the status message identifies the checkpoint where the item arrived, provides a timestamp for later examination, identifies the receiving party, etc. (Kärkkäinen, Ala-Risku and Främling [7]). By building a record of these status updates it is build accurate inventories of the checkpoint locations and trace the status history of the item. (Ala-Risku and Kärkkäinen [8]).
The checkpoint system is based on the correct identification of items as they arrive. This can happen manually (e.g. scanning a barcode) or automatically (e.g. by driving an RFID-tagged item through an RFID gate). Other status update possibilities also exist, such as electronic notifications from customs or warehouses (Shah [9]; Loebbecke and Powell [4]). In recent years, the growing use of GPS-trackers in fleet tracking and asset management has allowed the real-time tracking of goods, even on the item level. If the status information of the tracking system is also evaluated in real time (manually or by using intelligent information system), tracking enables the company to proactively detect and prevent logistical error - resolving or mitigating them before they cause significant problem (Stefansson and Tulanos [3]), Kärkkäinen et al. [6].

The collective term "track and trace" is often used (Huvio, Grönvall and Främling [10]; van Hoek [11]). Tracking stands for the management of information about to the current location of an item and tracing stands for the storage and retrieving of older information about the manufacturing/logistics of the item (Töyrylä [12]; van Dorp [13]). A third related term is suggested by Ruiz-Garcia, Barreiro, Rodriguez-Bermejo and Robla [14]: Tracking, Tracing and Monitoring (TTM). Monitoring relates to the ability of logistics companies to assure product quality during transportation. This is a concern especially in the case of perishable goods (foodstuffs, chemicals) (Jedermann & Lang [15]); Jedermann, Ruiz-Garcia & Lang[16]).

According to Zomer and Anten [17] logistical expenditure in Europe lies in the region of €800 billion (7% of GDP). The European Commission estimates that the freight transport mode shares are 45% road-based transport (trucks and trains) and 41% sea-based transport (Browne, Allen & Woodburn [18]). It is thus becoming more and more important for tracking systems to accommodate multi-modality. International logistics involves many different transport forwards and freight handlers, something which accentuates the challenge of building tracking systems that cover the whole supply chain (Leviäkangas, Haajanen, & Alaruuika [19]).

2.1 Tracking devices

The increasing use of RFID tagging internationally is making the creation of a checkpoint-style tracking system easier and easier. RFID tags have benefits to warehousing (Chow, Choy, Lee, & Lau [20]), material handling (Huang, Zhang, & Jiang [21]) and order processing (Philips [22]), but it can also be used in a wider geographical setting of physical distribution and supply chain inventory control (Jedermann, Behrens, Westphal, & Lang [23]).

However, RFID alone is not on its own a sufficient solution for wide international tracking, due to the need for an expensive infrastructure of RFID gates and readers (Wang and Potter [24]). The locational knowledge of the RFID network is only as good as its reader infrastructure deployed. RFID scans are also only take place at stand-still: a loaded truck cannot be scanned for inventory at speed. (Santa, Zamora-Izquierdo, Jara & Gómez-Skarmeta [25]).

For real-time tracking of items, GPS (Global Positioning System) and GSM (Global System for Mobile Communications) -tracking devices are used. Wireless internet such as 3G GPRS (General Packet Radio Service) is used to send location information to the tracking hub [25]. However, as these devices are significantly more expensive than an RFID tag (prices ranging from about 100€ to 400€ depending on functionality) they are more usually used to track a transport rather than a single item. But from a tracking system point of view, all items in a transport can of course be considered to share the same tracking device as describe by Bodamer [26].

According to Mondragon et al [27] the world market for fleet management and vehicle telematics (vehicle analytics and communication) is estimated to €3.9 billion and that more than 7 million vehicles are fitted with telematics systems annually.

However, the international functioning of such tracking devices is not entirely guaranteed. The SIM-cards needed to transmit the location information to the tracking system is the most limiting component - the operator providing the service must have a wide enough partner net to be able to guarantee coverage (and more importantly data packet transfer) where-ever the device travels. On the other hand, such considerations are not an issue for the majority of users - in Europe over 85% of truck fleets are operating relatively short-haul services within the national borders [27].
2.2 Integrating data from logistics chain

The choice of international forwarder and is often complex and depends on a number of different factors: freight costs, over-time performance (reliability of delivery), global/local expertise, track-record of safety, flexibility, availability capacity etc. (Dullaert, Maes, Vermimmen, & Witlox [28]; Blauwens, Vandaele, Van de Voorde, Vermimmen, & Witlox [29]; Witlox & Vandaele, [30]). A single transport company will mostly not possess all of these factors and therefore it is necessary for a company to be able to choose different transporters flexibly. A comprehensive tracking system must therefore be flexible and standardized enough to allow several different parties to contribute, or otherwise be completely independent of the forwarding companies. Dullaert, Neutens, Vanden Berghe, Vermeulen, Vermimmen and Witlox [31] note that the possible of exchanging tracking data between systems is influenced by (i) the size of the participating companies, (ii) the use of multiple transport modes, and (iii) the international dimension of transportation.

Tracking devices and tag scanning are not the only sources of good tracking data, however. Usually, a great deal of tracking data exists in various computer systems throughout the supply chain - the only problem lies in accessing them Warehouses, suppliers, transport companies, harbour operators, etc. -all can provide checkpoint data for a tracking system and precise location data for a specific area (warehouse location). As Hvolby and Trienekens [32] state, the balanced supply chain stands on functioning communication and information exchange between companies.

A higher degree of logistics communication and integration between supply chain partners has been seen to produce several benefits to the involved parties, as well as the end customer [33] [34] [35] [36] (Droge, Jayaram, & Vickery 2004; Flynn, Huo & Zhao 2010; Rosenzweig, Roth & Dean 2003; De Toni & Nassimbeni 1999). Stock, Greis and Kasarda [37] define logistics integration as "specific logistics practices and operational activities that coordinate the flow of materials from suppliers to customers throughout the value stream". This wide concept allows for many distinct solutions.

Researchers see improvements in lead time (Liu, Zhang & Hu [38]), customer satisfaction (Kim [39]) and customer services and service levels (Seidmann and Sundararajan [40]). Frohlich and Westbrook [41] see especially positive effects on delivery lead-time and on-time deliveries. These findings are not hard to accept - an error in routing or a delay in the delivery of a strategic component will not only incur monetary loss to the companies but also impacts long-term customer confidence. According to Fleisch, Ringbeck, Stroh, Plenge, Dittmann and Strassner [42], the customer claims that result from routing errors can be estimated to 2% of turnover in logistics.

There are of course also practical problems to overcome on the path to logistics integration. Hvolby and Trienekens [32] give some examples: 1) unwillingness to share data because of differing goals and an insufficient level of trust, 2) lack of consensus between companies about who owns and tends the functionality of the tracking system, 3) high costs of integrating parties, 4) difficulty to convince suppliers of the benefits of a tracking system. Dullaert et al. [31] also mention these same problems in their research. They also see that since the successfully sharing tracking data in the supply chain depends on the trust and willingness of the companies to share, data privacy from other users and data safety (from outside theft) is a complex obstacle to logistics integration.

3. REQUIREMENTS ANALYSIS FOR PROJECT BUSINESS

After technology evaluation, a requirements analysis was conducted with project managers and logistics managers of a globally operating project company. The results of the analysis show that requirements for tracking and tracing system for a manufacturing company operating project logistics can be summarized in following bullets:

(1) Combining project work package structure and management of shipments and deliveries
(2) Open connections for transport booking and status information updates
(3) One time vendors and high volume suppliers feeding shipment information in
(4) Support for both passive checkpoint information as well as active tracking devices
(5) Support for varying transportation routes and durations.
4. SOLUTION PROPOSAL

An integrated logistics tracking portal was developed to fulfill the requirements. The outcome of the development process was a cloud-based enterprise portal, which receives periodic input from ERP project management system. Planned shipments, deliverables, and material handling units (containers, pallets, boxes) are described with hierarchy. Figure 1 illustrates how each product is coded on crate level, crates are connected to pallets, and pallets may be connected to container information and containers at each of the time on transportation vehicles. Each of the material handling unit have unique number printed as visible RFID/barcode label.

![Packing hierarchy](image)

**Figure 1** – Packaging hierarchy used for tracking inheritance.

From data model point of view, transportation checkpoints are connected to each project work breakdown structure and packaging hierarchy. Checkpoint transactions, which are typically reading check-in or check-out information of material handling units, are collected from varying sources. Vendors are using supplier portal to feed in information and print out case labels with unique tracking number according to SSCC standard. Transport bookings are also placed with the same centralized system. Transport companies can provide checkpoint information to the portal by using EDI status messages. Consolidation points, such as warehouses, are using automatic RFID tag reading and feeding in information for loading, unloading, repackaging etc. Once all the deliveries are received according to plan to consolidation point, the outbound logistics can be initiated. Checkpoint information can be read finally at the customer site by using mobile application. During the transportation in both inbound and outbound, tracking devices may be used for more expensive deliveries. Tracking devices are sending information several times per day including location, temperature, humidity and shock. For those parts of transportation, where location information cannot be sent, for example ocean journeys, ship IMO tracking service is used. Sea vessel tracking information is combined according to figure 1 data hierarchy. Figure 2 illustrates checkpoint and tracking data use at each part of the supply chain.
Once all the data has been frequently input from various parts and companies along the supply chain into the tracking and tracing portal, a user interface can be generated. Figure 3 shows how user can search his own delivery projects, drill down to project shipments, deliveries and each material handling unit. Each material handling unit has planned stages originating from ERP data and this is connected to supply chain data fed in by vendors, distribution centers, transportation companies and autonomous tracking devices. History of each checkpoint transaction and sensory data are stored on centralized database. The portal can supply up to date information for external systems, such as ERP and various mobile client software.

Figure 3 – User interface of logistics tracking portal showing package structure and temperature, vibration records on container.

Figure 4 shows data elements used in the centralized portal system for building the centralized tracking and tracing information for each project delivery element.
5. CONCLUSIONS

Supply process development for multi-project management environment relates to relationship and information management between logistics partners [43]. Tracking and tracking systems have been traditionally developed for purposes of transportation companies. An analysis of global manufacturing company with several factories, suppliers, consolidation points and customer sites show that similar needs exist in project logistics. In this paper an attempt has been made to propose a company level logistics system which is able to communicate with ERP system, RFID systems, transportation companies and tracking devices. All sensory information is structured according to data model and stored on a cloud based centralized database.

The system has been piloted in a real context and integrations have been tested with vendors and transportation companies. The developed system has still limitations, including clear definition of ownership of the data, but it also shows that such enterprise centric solution can be developed for a project company, not only from transportation logistics point of view but project logistics elements such as WBS, deliveries and shipments. In the future, it is expected that larger companies are going to build more such real-time logistics information providing systems. Open architectures and use of standards allow various companies to connect such systems.

6. REFERENCES


EVALUATING THE STRATEGIC RELEVANCE OF LOGISTICS:
INSIGHTS FROM MULTINATIONAL CORPORATIONS.

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Abstract
This paper examines the strategic relevance of logistics in multinational corporations. This is done by utilizing a quantitative content analysis on annual reports of 360 multinational corporations over a period from 1998 to 2008, resulting in 3,051 observations. From 1998 to 2002 the strategic relevance of logistics in European multinational corporations was considerably higher than in their North-American or Asian counterparts. From 2003 to 2008 the strategic relevance is more pronounced in Asian corporations. Using the GICS industry classification scheme, we show that the strategic relevance is more pronounced within the sectors industrials, information technology, consumer discretionary and consumer staples compared to the sectors energy, telecommunication services and utilities. This is the first paper that assesses the strategic relevance of logistics in multinational corporations via quantitative content analysis, providing exploratory findings and a framework for further research.

Keywords: logistics, supply chain management, content analysis, multinational corporations, corporate communications

1. INTRODUCTION

Logistics and supply chain management have become increasingly important in recent years. The growing internationalization and globalization process has led to a further rise in relevance [1,2,3,4]. Especially the growing distances between the participating companies result in increasing problems in ensuring a most efficient and effective supply at each value-added step. The same applies for the information flow between the companies involved in an increasingly complex and global supply chain.

To ensure an efficient flow of goods and information the alignment of management is becoming more flow-oriented [5,6] and is not limited to the single company itself, but rather all strategically important suppliers as well as customers have to be integrated into the decision process [7,8]. Following the concept of a flow-based process optimization, logistics as an instrument for ensuring an effective and efficient flow of objects is gaining further importance. Therefore logistics is no longer limited to the realization of operative transport, handling, and storage activities, but has emerged in terms of a flow-oriented leadership as a new management paradigm [9,10]. Supply chain management – as a new, modern level of logistics – with a clear company overarching orientation is subject to the same developments and is already playing an important role in corporate management [11,12,13,14].

Multinational corporations are often characterized by complex international linkages between independent companies. Therefore, the management of the various object and information flows is of particular relevance for multinationals and the problems described are especially relevant in this area [15,16].

The aim of the paper is to examine to what extent logistics as a new flow-oriented management paradigm is implemented within multinational corporations. Since empirical evidence regarding the implementation of a flow-oriented management paradigm is scarce [17,18] and logistics ratios are not widely available [19,20], we try to measure this aspect using communication efforts concerning logistics as a useful proxy. Communication efforts mirror the management objectives and can be used as a substitute for the strategic relevance [21,22,23]. We decided to use annual reports to gain comprehensive and comparable data within this international sample, leading to the following research question:
RQ1. How has the strategic relevance of logistics within multinational corporations developed in the period from 1998 to 2008?

Furthermore we grouped the companies into different world regions [24], looking for possible differences within the strategic relevance, leading to research question two:

RQ2. Does the geographical heritage have an effect on the strategic relevance of logistics within multinational corporations?

Most empirical studies that examine the strategic relevance, find differences on an industrial level [for instance 25], leading to research question three:

RQ3. Does the associated industry have an effect on the strategic relevance of logistics within multinational corporations?

Due to the fact that there is no prior research to build on, this study is highly exploratory, serving as a first step to empirically validate a model in order to estimate the strategic relevance of logistics.

The paper is structured as follows. We are providing a literature review on the subjects of logistics and supply chain management as well as content analyses in these academic disciplines. In the methodological part we describe the composition of our sample and the content analysis as a research approach. This is followed by a presentation and discussion of the results, providing academic and practical contributions.

2. LITERATURE REVIEW

2.1 Logistics and supply chain management

The evolutionary process of logistics can be divided into three main stages [26,27]. The first stage describes logistics as a functional specialization on activities associated with the spatial and temporal transformation of goods. Logistics departments in companies are mostly aimed directly at operational, material flow-related activities and play only a minor role in the context of strategic planning [28]. The second stage extends logistics to an enterprise-divisional and cross-company coordination of all flows of materials, goods and information. In this function, logistics gains significantly strategic relevance [29,30]. In the latest stage logistics is seen as a new leadership doctrine. Logistics is now interpreted as the management of flow systems. The entire company is designed as flow-oriented and corporate management is focused on logistics objectives [31,32,33]. According to the third stage logistics can be described as a modern management concept for the development, design, management, and implementation of effective and efficient flows of objects (goods, information, money and financial flows) in enterprise-wide and cross-company value added systems [34].

Definitions of supply chain management can be divided into two alternative schools of thought. Authors of the first group define supply chain management as a special form of logistics or even as synonymous [35,36]. The second group interprets supply chain management more broadly as a kind of general cooperation or relationship management [37,38]. As representatives of the second group, Johnson et al., 1999 describe supply chain management as a “… somewhat larger concept than logistics, because it deals with managing both the flow of materials and the relationships among channel intermediaries from the point of origin of raw materials through to the final consumer” [39].

In this paper we are following the definition of Simchi-Levi et al., 2009, who emphasize that “… we will not distinguish between logistics and supply chain management …” [40]. Considering both terms as synonymous, supply chain management can be defined as a modern concept for corporate networks to exploit cross-company success potentials by the development, design, management, and implementation of effective and efficient goods, information, money, and financial flows [41]. This definition shows the close relationship to logistics. For that reason we will only use the term logistics in the remainder of the article.

2.2 Content analyses in logistics

While content analysis has been well established in various areas of management and social sciences [42,43]; in the field of logistics it is limited to only a few studies [44]. These studies are mainly focused on the determination of different research methodologies or approaches and the influence of other disciplines on logistics.
Spens and Kovács, 2006 for instance, observed three journals from 1998 to 2002 identifying different research approaches in logistics [45]. The authors distinguished between deductive, inductive and abductive research processes. Seuring and Gold, 2012 instead analyzed different literature review papers and compared them in terms of primary research approaches [46]. Focused on the influence of other disciplines onto logistics – for example marketing, accounting, psychology or sociology – Stock, 1997 analyzed four journals over a period of 16 years (1980 – 1996) [47]. Further examples of the use of content analysis in logistics are Craighead et al., 2007; Croom et al., 2000; Sachan and Datta, 2005; Frankel et al., 2005; Anderson et al., 2007 and Hazen et al., 2012 [48,49,50,51,52,53]. To date, we could not find any study utilizing content analysis examining corporate disclosure of any kind (e.g. annual reports or form 10-K) regarding logistics matters.

Corporate disclosure plays a significant role within content analysis in the area of business communication research [54,55]. They cover for instance the examination of the readability of annual reports [56], the use of negative or positive expressions [57] and special linguistic structures as well as rhetorical elements [58]. Other studies examine social responsibility efforts [59,60], environmental aspects [61,62] or risk reporting [63,64]. So far, the analysis of the communication of logistics efforts within annual reports still represents an unexplored field of research.

3. METHODOLOGY

3.1 Data collection

We chose the 500 publicly listed firms with the highest expenditures on research and development worldwide, according to the British Department for Business Innovation and Skills. Since logistics is highly dynamic [65], firms with high expenditures on research and development tend to have more adaptive capabilities suitable for fast changing business environments [66]. Due to data availability, we had 360 companies in the final sample.

Concerning the geographical differences, we grouped the companies into three different world regions: North-America, Europe and Asia. Only 11 out of 360 companies cannot be assigned to this geographical classification. Two companies’ headquarters are located in Australia, one in the Netherlands Antilles, one in Brazil and seven values are missing. To examine if the strategic relevance of logistics varies across industries, we grouped the firms according to the Global Industry Classification Standard (GICS). Using the GICS-classification on a two-digit sector level, 54 companies can be grouped into the consumer discretionary, 12 into the energy, 55 into the health care, 80 into the industrials, 87 into the information technology, 36 into the materials and 14 into the telecommunication services sector. Nine companies can be grouped into the consumer staples and six companies into the utilities sector, but are not regarded further due to insufficient representation. No company within the sample belongs to the financial sector and seven values are missing. To derive a comparable international overview, we examined only annual reports, no form 10-K or 20-F was included. Our sample period ranges from 1998 to 2008, since before 1998 annual reports were not widely available in a digital format and ruled out the years after 2008 because of possible side effects of the financial crisis. Since not all annual reports from the companies were accessible within the sample period, 3051 annual reports were examined in this study.

3.2 Measurement

To examine the strategic relevance of logistics we used quantitative content analysis with the software MAXQDA, which is a German-based software program designed for qualitative and quantitative data, text and multimedia analysis [67].

Content analysis as a research method is a systematic and objective technique to describe and quantify phenomena in the social sciences [68,69,70]. The quantitative part focuses on fixed selected characteristics, such as word frequencies, to ensure a high degree of reproducibility [71]. This is based upon the thought that the occurrence of certain words can be important indicators for the identification of hidden agendas and motives [72]. Empirical studies conducting quantitative analysis suggest that it is a suitable instrument for analyzing strategic orientation of companies [73,74,75]. To capture the strategic relevance of logistics we were assessing the terms ‘logistics’ and ‘supply chain’. The number of logistics and supply chain terminologies is then divided by the length of the respective annual report. For instance Boeing used in its
2007 annual report 20 times logistics and supply chain terminologies with an annual report consisting of 60,661 words (20/60,661 = 0,0003296). This calculation is done for all years and all annual reports. Afterwards we derive mean values on a geographical and industrial level.

4. RESULTS

4.1. The strategic relevance of logistics

Figure 1 represents the results of the quantitative content analysis showing the mean of the entire sample, and the mean after grouping the companies into three major geographical regions (North America, Europe and Asia). The numbers below the charts show the mean values for the occurrences of the terms ‘logistics’ and ‘supply chain’ divided by the number of words of the respective annual report. Looking at the entire sample, a positive trend can be observed in the strategic relevance of logistics within multinational corporations (see the dashed line in figure 1). Over the entire period from 1998 to 2008 an increase of 10.68% is recorded. The values for the single years are subject to fluctuations, with high values in 2005 and 2007 and low values in 1999 and 2002. Hence for RQ1 we propose that:

P1. The strategic relevance of logistics within multinational corporations increased by 10.68% during the period 1998 to 2008.

Looking at the geographical regions, differences become easily apparent. From 1998 to 2002 the strategic relevance of logistics was highlighted the most in Europe followed by North America and Asia. From then on, the strategic relevance declined in Europe and at the same time increased in Asia. Therefore, from 2002 to 2008 logistics was most pronounced in Asia, followed by Europe and North America. Over the entire period opposite trends for the geographical regions appear. In Europe there was a strong increase of 16.14% from 1998 to 2000, followed by a steady decrease of 24.93%. In North America a clear trend is difficult to identify, however, over the entire period a low positive growth of 1.97 % can be seen. The development of logistics in Asia is diametrically opposite. After the first three years (1998 to 2000) a strong increase of 117.36% was recorded from 2000 to 2007. Only in 2008, the value decreased again by 17.74%. The highest values for the strategic relevance of logistics over the entire period and for all geographical regions occurred from 2005 to 2007 in Asia with increasing values; the lowest ones in North America in 2002 and 1999. In 2002, for instance, the mean value evaluating the strategic relevance of logistics in Europe was 134% higher than in North America. Therefore we propose concerning RQ2:

P2. The geographical origin has an effect on the strategic relevance of logistics, with considerably higher values for European and Asian companies.

Concerning the industrial distribution clear differences can be seen, too (see figure 2). The differences between sectors are partially up to 97.7% (between industrials and telecommunication services in 1998). The logistics efforts seem to be most pronounced in the industrials sector with the highest values for each year, except 2006 with the consumer discretionary sector ranking first. Over the entire period from 1998 to 2008 an increase of 20.41% can be recorded. The highest values for the industrial sector and thus for the entire sample occur in the years 2008, 2004 and 2007.

The strongest increase is recorded within the consumer discretionary sector. After a relatively constant progression over the first five years, the relevance rate rose from 2002 to 2007 by 75.41%, but then the value decreased again in the following year by 30.31%.

The information technologies sector has constantly relatively high values as well, even if they are far below those of the other industries. From 1998 to 2002 information technologies reported the second highest values after the industrial sectors. Afterwards, however, it was overtaken by the consumer discretionary sector. Over the entire period the value for information technologies remains relatively constant with a peak in 2005 and losses in 2007 and 2002.

Regarding the strategic relevance of logistics the materials sector follows in fourth rank with a great distance to the sectors of telecommunication services and energy. Starting with a small increase (+14.71%) up to 2005, a strong decrease of 39.67% occurred in the materials sector in the last three years.
Figure 1 – The strategic relevance of logistics on a geographical level

<table>
<thead>
<tr>
<th>Year</th>
<th>Asia</th>
<th>Europe</th>
<th>North America</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>1.01E+04</td>
<td>1.01E+04</td>
<td>1.01E+04</td>
<td>1.01E+04</td>
</tr>
<tr>
<td>2000</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2001</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2002</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2003</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2004</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2005</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2006</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2007</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
<tr>
<td>2008</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
<td>1.02E+04</td>
</tr>
</tbody>
</table>
### Figure 2 – The Strategic Relevance of Logistics on an Industrial Level

<table>
<thead>
<tr>
<th>Year</th>
<th>Consumer Discretionary</th>
<th>Energy</th>
<th>Health Care</th>
<th>Industrials</th>
<th>Information Technology</th>
<th>Materials</th>
<th>Telecommunication Services</th>
</tr>
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<tbody>
<tr>
<td>1998</td>
<td>1,01E-04</td>
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<td>5,52E-05</td>
<td>1,48E-04</td>
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<td>1,03E-04</td>
<td>3,40E-06</td>
</tr>
<tr>
<td>1999</td>
<td>1,01E-04</td>
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<td>2,41E-05</td>
<td>1,40E-04</td>
<td>1,04E-04</td>
<td>6,95E-05</td>
<td>1,30E-04</td>
</tr>
<tr>
<td>2000</td>
<td>9,70E-05</td>
<td>3,06E-05</td>
<td>1,24E-04</td>
<td>1,72E-04</td>
<td>1,13E-04</td>
<td>9,83E-05</td>
<td>1,21E-04</td>
</tr>
<tr>
<td>2001</td>
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<td>2,81E-05</td>
<td>4,86E-05</td>
<td>1,69E-04</td>
<td>1,39E-04</td>
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<td>1,17E-04</td>
</tr>
<tr>
<td>2002</td>
<td>1,22E-04</td>
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<td>1,13E-04</td>
<td>3,76E-05</td>
<td>9,80E-05</td>
</tr>
<tr>
<td>2003</td>
<td>1,39E-04</td>
<td>4,86E-05</td>
<td>4,77E-05</td>
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<td>1,36E-04</td>
<td>9,80E-05</td>
<td>9,84E-05</td>
</tr>
<tr>
<td>2004</td>
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<td>5,06E-05</td>
<td>1,47E-04</td>
<td>1,36E-04</td>
<td>8,87E-05</td>
<td>9,84E-05</td>
</tr>
<tr>
<td>2005</td>
<td>1,67E-04</td>
<td>9,70E-05</td>
<td>9,80E-05</td>
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<td>1,36E-04</td>
<td>8,59E-05</td>
<td>9,84E-05</td>
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<tr>
<td>2006</td>
<td>1,73E-04</td>
<td>1,20E-04</td>
<td>8,83E-05</td>
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<td>1,36E-04</td>
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<td>9,84E-05</td>
</tr>
<tr>
<td>2007</td>
<td>1,20E-04</td>
<td>1,13E-04</td>
<td>8,83E-05</td>
<td>1,74E-04</td>
<td>1,36E-04</td>
<td>3,76E-05</td>
<td>9,84E-05</td>
</tr>
<tr>
<td>2008</td>
<td>1,21E-04</td>
<td>1,13E-04</td>
<td>8,83E-05</td>
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<td>1,36E-04</td>
<td>3,76E-05</td>
<td>9,84E-05</td>
</tr>
</tbody>
</table>
The relevance within the health care sector experienced strong fluctuations within the years 1998 to 2001, followed by a steady increase, but declining in the last two years. Even if the health care sector outperformed the materials sector in the years 2000, 2006, 2007 and 2008, overall, the strategic relevance of logistics is more pronounced in the later sector.

The last two sectors energy and telecommunication services follow at a clear distance. Both industries alternate repeatedly regarding the highest value. The lowest values for all sectors during the entire period occurred in 1998 for the telecommunication services sector and in 1999 for the energy sector. Overall, however, even for these two sectors an increase is reported. The energy sector rose from 1998 to 2008 by 51.63% and the telecommunication services sector due to the very low value in 1998 even by 1,103.11%. Compared to the year 1999 the increase was just 23.92%. Therefore, regarding RQ3 we propose that:

P3. *The industry has an effect on the strategic relevance of logistics being more pronounced within the sectors industrials, consumer discretionary and information technology.*

5. DISCUSSION

This study investigates the strategic relevance of logistics in annual reports of multinational corporations. To our knowledge, this is the first study that quantifies and elaborates on such matter with this research approach.

5.1 Summary of findings

We have found that the strategic relevance of logistics within multinational corporations is increasing over the sample period. Between 1998 and 2008 the relevance of logistics received a growth of 10.68%. This indicates an increasing strategic relevance of logistics, which can be interpreted as a higher awareness of logistics as a new flow-oriented management paradigm. The increased relevance of logistics can be attributed to the fact that supply chain management, as the highest level of logistics, became increasingly important in scientific literature around the turn of the millennium [76]. Due to the growing scientific debate a greater awareness among the companies could be achieved, which is reflected in a higher relevance rate within the corporate reporting of multinational corporations. Another aspect might be the growing export orientation of multinational corporations and the global enlargement of the supply chains. This finding is in line with Pope, 2011; Prasad and Sounderpandian, 2003 and Tongzong, 2012, who have discovered as well that logistics is becoming increasingly important, especially due to growing globalization effects [77,78,79].

We also showed that the strategic relevance of logistics varies across geographical regions. From 1998 to 2002 European corporations communicated logistics far more often than their North American and especially Asian counterparts. Afterwards, from 2003 to 2008, Asian corporations led the ranking. This implies that European multinational corporations can be seen as pioneers in this area, while there was a slight delay of the strategic relevance within Asian corporations. It also implicates that the strategic relevance of logistics was more pronounced in European corporations from 1998 to 2002, while from 2003 to 2008, the strategic relevance within Asian corporations was the highest. The subsequent rise of the strategic relevance in Asia might be attributed to the increasing position of Asian multinational corporations in the world market.

Within the last years Asian corporations tend to be more export oriented than European or American corporations [80]; making logistics a core competency for Asian corporations which is mirrored by relatively high values in communicating logistics efforts.

Regarding the industrial differentiation, we showed that the strategic relevance of logistics is more pronounced within the sectors industrials, consumer discretionary and information technology. The industrials sector includes the areas engineering and building products, electrical equipment and industrial machinery. These areas are characterized by complex manufacturing processes and a high degree of cross-company division of labor; therefore, the relevance of logistics is quite high. The same applies to the consumer discretionary sector, which includes the automobiles and components subsector. The automotive industry is usually considered as the role model for logistics [81,82]; therefore it is no surprise that the strategic relevance of logistics is already very advanced in this sector. The sectors with the lowest relevance rate – energy and telecommunication services – are parts of the service sector. In these areas the procurement and distribution of goods as well as the logistics support of the production processes is traditionally very low; this is mirrored in a low strategic relevance.
5.2 Limitations, implications and further research

Due to data availability we examined only the years 1998 to 2008, while further research might include a larger period. Another constraint of this study can be the concentration on multinational corporations; the results can differ for small and medium size corporations. Since we conducted a highly exploratory study across various industries and geographical regions, a specified research focus, for instance, on single countries or single industries might lead to different results. Furthermore, we analyzed only the occurrence of the terminologies “logistics” and “supply chain”; further terminologies in the area of logistics such as procurement, distribution or transportation were not included due to multiple meanings.

Since this is the first study of its kind, the contributions are principally twofold. First, it is supposed to provide a starting point for further research. The study works as a first step to develop a model for estimating the strategic relevance of logistics and can serve as a key figure in the logistics context. This study is trying to lay ground for consecutive studies using more elaborate statistical procedures such as ANOVA regarding the geographical and industrial distribution of corporations. In our study we focused only on annual reports; another interesting point would be the analysis of different communication channels, for instance, corporate websites or printed media. Further research areas are the comparison of logistics communication with other communication areas such as marketing or finance and the detailed analysis of specific geographical regions or industries. Second, the results might serve as a key figure for researchers and practitioners to assess the strategic relevance of logistics in corporations.

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AN EQUITABLE OPTIMIZATION OF COST AND SERVICE LEVEL IN THE PRESENCE OF SUPPLY CHAIN DISRUPTION RISKS

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Abstract
This paper presents a new decision-making problem of equitably efficient optimization of a supply chain under disruption risks. Given a set of customer orders for products, the decision maker needs to select suppliers of parts required to complete the orders, allocate the demand for parts among the selected suppliers, and schedule the orders over the planning horizon, to equitably optimize expected cost and customer service level. The supplies are subject to independent random local disruptions that are uniquely associated with a particular supplier and to random regional disruptions that may result in disruption of all suppliers in the same region simultaneously. The obtained combinatorial stochastic optimization problem is formulated as a mixed integer program with the ordered weighted averaging aggregation of the two objective functions. Numerical examples and computational results are presented.

Keywords: supplier selection, customer order scheduling, disruption risks, equitable optimization, MIP

1. INTRODUCTION
The optimization of material flows in global supply chain networks focuses on a variety of different optimality criteria. In view of the global competition and flow disruption risks, how to best schedule the flows with reduced cost and higher customer service level, becomes a crucial issue. Cost is the most commonly used criterion for a global supply chain performance, while customer service level measures the percentage of customer demand satisfied on time. The above two performance metrics are basic to the control and optimization of flows in global supply chain networks and the decision makers often do not have preference to any objective, i.e., the two objectives are equally important. In this case, it is crucial to generate an equitable solution, in which all normalized objective function values are as much close to each other as possible. In order to generate such kind of solutions, the lexicographic minimax method, as a special case of the ordered weighted averaging aggregation [1] can be applied. The lexicographic minimax problem can be transferred to a lexicographic minimization problem and recently in [2] and [3] an approach was developed to transfer the lexicographic minimax problem to a minimization optimization problem, instead of a lexicographic minimization problem, which needs to solve a sequence of optimization problems iteratively.

The coordinated selection of part suppliers, allocation of order quantities and scheduling of customer orders may particularly help to optimize performance of a global supply chain network under disruption risks due to unexpected natural or man-made disasters such as earthquakes, fires, floods, hurricanes or labor strikes, economic crisis, terrorist attack, etc. The research on supplier selection under disruption risks is very limited. For example, in [4] the impacts of supply disruption risks was considered on the choice between the single and dual sourcing methods in a two-stage supply chain with a non-stationary and price-sensitive demand. In [5] a portfolio approach was proposed for the supplier selection and order quantity allocation under disruption risks and the two popular percentile measures of risk, Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR) were applied for managing the risk of supply disruptions, e.g. [6]. In [7] a new stochastic mixed integer programming approach was proposed to integrated supplier selection, order quantity
allocation and customer orders scheduling in a multi-stage supply chain under local and global disruption risks to minimize expected or expected worst-case cost (CVaR).

The major contribution of this paper is that it proposes a new stochastic MIP model for the integrated selection of supply portfolio and scheduling of customer orders in a supply chain under local and regional disruption risks, to equitably optimize expected cost and expected service level.

The paper is organized as follows. The description of the integrated selection of suppliers and scheduling of customer orders in the presence of supply chain disruption risks is presented in Section 2. The stochastic mixed integer program for equitably efficient optimization of expected cost and service level is developed in Section 3. Numerical examples and some computational results are provided in Section 4, and final conclusions are made in the last section.

2. PROBLEM DESCRIPTION

Consider a three-stage customer driven supply chain in which various types of products are assembled by a single producer to meet customer orders, using the same critical part type that can be manufactured and provided by many suppliers.

Let $I = \{1, \ldots, M\}$ be the set of $M$ suppliers, $J = \{1, \ldots, N\}$ the set of $N$ customer orders for products and $T = \{1, \ldots, H\}$ the set of $H$ planning periods.

Denote by $b_j$ and $d_j$, respectively the size and the due date of customer order $j \in J$. Let $a_i$ be the unit requirement for the critical part of each product in customer order $j \in J$. The total demand for all parts is $A = \sum_{j \in J} a_i b_j$ and the total demand for all products is $B = \sum_{j \in J} b_j$. Let $o_i$ be the unit purchasing price of parts from supplier $i$ and denote by $e_i$ the fixed cost of ordering parts from supplier $i$.

The order preparation and transportation time of a shipment from supplier $i$ to the producer is constant and equals to $\sigma_i$ periods so that the parts ordered from supplier $i$ are delivered in period $\sigma_i$ and then can be used for the assembly of products in period $\sigma_i + 1$, at the earliest.

The producer does not need to pay for ordered parts and undelivered due to supply disruptions. However, it is charged with a much higher cost of delayed or unfulfilled customer orders for products, caused by the shortage of parts. Let $g_j$ and $h_j$ be, respectively the per unit and per period penalty cost of delayed customer order $j \in J$ and the per unit total penalty cost of unfulfilled customer order $j \in J$.

Denote by $C_t$ the capacity of producer in planning period $t \in T$, and by $c_j$ the unit capacity consumption for each product in customer order $j \in J$.

Assume that the suppliers are located in a number of disjoint geographical regions and denote by $\mathcal{R}$ the subset of suppliers in region $r \in \mathcal{R}$. The supplies of parts are subject to random local disruptions that are uniquely associated with a particular supplier and to regional disasters that may result in disruption of all suppliers in the same region simultaneously. Denote by $p_i$, the local disruption probability for supplier $i \in I$ and by $p_r$ the probability of regional disruptions of all suppliers $i \in I$ in region $r \in \mathcal{R}$.

The regional disasters in each region and the local disasters at each supplier are assumed to be independent events. Let $\pi_i = p_i^r + (1 - p_r) p_i$, be the disruption probability of every supplier $i \in \mathcal{I}, r \in \mathcal{R}$.

Denote by $P_s$ be the probability that disruption scenario $s$ is realized, where each scenario $s \in S$ is comprised of a unique subset $I_s \subset I$ of suppliers who deliver parts without disruptions, and $S = \{1, \ldots, q\}$ is the index set of all scenarios (note that there are a total of $q = 2^M$ potential disruption scenarios). For each scenario $s \in S$, the supplies from every supplier, $i \notin I_s$, can be disrupted either by a local or a regional disaster event. The probability $P_s$ for each disruption scenario $s \in S$ with the subset $I_s$ of non-disrupted suppliers, and with all possible combinations of different disaster events considered, is $P_s = \prod_{r \in \mathcal{R}} P_{s_r}$, where $P_{s_r}$ (see, (1) in Appendix), is the probability of realizing of disruption scenario $s$ for suppliers in $I_r$. 


3. PROBLEM FORMULATION

In this section the time-indexed stochastic MIP model ECS is proposed (see, Appendix for all mathematical formulae) for the equitably efficient optimization of supplier selection and customer order scheduling to minimize expected cost per product and maximize expected service level, i.e., the fraction of customer orders filled on or before their due dates.

The following three basic decision variables are introduced in the proposed MIP model:

1. Supplier selection variable: $u_i=1$, if supplier $i$ is selected; otherwise $u_i=0$,  
2. Order-to-period assignment variable: $v_{jt}^s=1$, if under disruption scenario $s$ customer order $j$ is assigned to planning period $t$; otherwise $v_{jt}^s=0$, 
3. Demand allocation variable: $w_i \in [0,1]$ is the fraction of total demand for parts ordered from supplier $i$.

Let $E_1$, (2), be the minimized expected cost per product and $E_2$, (3), the maximized expected customer service level. In order to avoid dimensional inconsistency among various objectives, the values of the optimized objective functions are scaled into the interval $[0,1]$. The normalized objective functions $f_1$ and $f_2$ are defined in (4) and (5), respectively ($\bar{E}_1, \bar{E}_2$ are minimum, maximum values of $E_1$ and $E_2$, $\bar{E}_3, \bar{E}_4$ are minimum, maximum values of $E_3$).

The mixed integer program ECS for the equitably efficient optimization of supplier selection and customer order scheduling to equitably minimize expected cost per products and maximize expected service level is formulated below.

**Model ECS:** Equitably efficient supplier selection and customer order scheduling to minimize expected Cost and maximize expected Service level

Minimize $E$(6)

subject to (4), (5), (7) and

Demand allocation constraints:
- the total demand for parts must be fully allocated among the selected suppliers, (8),
- demand for parts cannot be assigned to non-selected suppliers, (9),

Order-to-period assignment constraints:
- for each disruption scenario $s$, each customer order $j$ is either scheduled during the planning horizon or unscheduled and rejected, (10),
- for each disruption scenario $s$ and each planning period $t$, the cumulative demand for parts of all scheduled customer orders scheduled in periods $I$ through $t$ cannot exceed the cumulative deliveries of parts in periods $I$ through $t-1$, from the non-disrupted suppliers $i \in I$, (11),
- for each disruption scenario $s$, the total requirement for parts of scheduled customer orders is not greater than the total supplies from the non-disrupted suppliers $i \in I$, (12),

Producer capacity constraints:
- for any period $t$ and each disruption scenario $s$, the total demand on capacity of all customer orders scheduled in period $t$ must not exceed the producer capacity available in this period, (13),

Non-negativity and integrality conditions: (14) - (17).

The objective function (6) subject to constraints (7) represents the so-called ordered weighted averaging bi-criteria problem, where $\lambda_i$ are unrestricted variables, while nonnegative variables $\delta_{ki}$ (14) represent, for outcome values $f_k$ their upside deviations from the value of $\lambda_i$, e.g., [1,2].
3.1. Minimum and maximum values of the objective functions

In this subsection the minimum and maximum values for all objective functions are calculated to determine the normalized values of all objective functions, $f_1$, (4), $f_2$, (5), that is, the values of the optimized objective functions scaled into the interval $[0,1]$. Note that the cost and the service level objectives are in conflict. Therefore, the minimum and maximum values of expected cost $E_{1}, \bar{E}_{1}$, and expected service level, $E_{2}, \bar{E}_{2}$, are obtained by solving the following mixed integer programs:

**Model EC:** Supplier selection and customer order scheduling to minimize Expected Cost per product

Minimize $E_1$, (2),
subject to (8) - (13), (15) - (17).

**Model ES:** Supplier selection and customer order scheduling to maximize Expected Service level

Maximize $E_2$, (3)
subject to (8) - (13), (15) - (17).

In problem EC, $E_1$ is the minimized objective function, while $E_2$ is not considered. In problem ES, $E_2$ is the maximized objective function, while $E_1$ is not considered. Thus, by solving problem EC, the minimum value $\bar{E}_1$ of $E_1$ and the minimum value $\bar{E}_2$ of $E_2$ are determined. Similarly, by solving problem ES, the maximum value $\bar{E}_2$ of $E_2$ and the maximum value $\bar{E}_1$ of $E_1$ are determined.

4. COMPUTATIONAL EXAMPLES

In this section some computational examples are presented. The following parameters have been used for the example problems: $H=10$, $M=9$, $N=25$, $q=2^M=512$;

$R=\{1,2,3\}$, $I^1=\{1,2,3\}$, $I^2=\{4,5,6\}$, $I^3=\{7,8,9\}$;

$\sigma_i \in \{1,2\}$, $i \in I^1$, $\sigma_i \in \{2,3\}$, $i \in I^2$, $\sigma_i \in \{3,4\}$, $i \in I^3$;

$a_j \in \{1,2,3\}$, $b_j \in \{500,...,5000\}$, $c_j \in \{1,2,3\}$, $j \in J$;

$C_i=38000$, $i \in T$;

$d_j \in \{1+\min(\sigma_i), ... , H\}$. $j \in J$;

$e_i \in \{5000,...,10000\}$, $i \in I^1$, $e_i \in \{10000,...,15000\}$, $i \in I^2$, $e_i \in \{15000,...,30000\}$, $i \in I^3$;

$o_i$. $i \in I$ - uniformly distributed over $[11,16]$, $[6,11]$ and $[1,6]$, respectively for suppliers $i \in I^1$, $i \in I^2$ and $i \in I^3$;

$g_j = a_j \max_i(o_i)/350$, $h_j = 2a_j \max_i(o_i)$, $j \in J$;

$p_i$. $i \in I$. $i \in I^1$, $i \in I^2$ and $i \in I^3$.

$p_1=0.001$, $p_2=0.005$, $p_3=0.01$.

The unit price per part $o_i$ and the disruption probability $\pi_i = p_i^\prime + (1 - p_i^\prime)p_i$ for every supplier $i \in I$, $r \in R$ are shown in Fig.1.
Figure 1 – Basic characteristics of suppliers

Figure 2 – Expected production schedules

Table 1 – Example of solution results

<table>
<thead>
<tr>
<th>Model</th>
<th>Var.</th>
<th>Bin.</th>
<th>Cons.</th>
<th>Nonz.</th>
<th>Expected Cost ($E_1$)</th>
<th>Suppliers Selected (% of total demand)</th>
<th>Expected Service Level ($E_2$)</th>
<th>Expected Cost ($E_3$)</th>
<th>Suppliers Selected (% of total demand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC</td>
<td>100468</td>
<td>100459</td>
<td>21341</td>
<td>765902</td>
<td>7.66</td>
<td>7 (100%)</td>
<td>67.60%</td>
<td>9.31</td>
<td>2(6%), 6(13%), 7(81%)</td>
</tr>
<tr>
<td>ES</td>
<td>100468</td>
<td>100459</td>
<td>21341</td>
<td>765902</td>
<td>99.62%</td>
<td>1(48%), 2(31%), 3(21%)</td>
<td></td>
<td>25.64</td>
<td></td>
</tr>
<tr>
<td>ECS</td>
<td>100476</td>
<td>100459</td>
<td>21347</td>
<td>921880</td>
<td></td>
<td></td>
<td></td>
<td>96.06%</td>
<td></td>
</tr>
</tbody>
</table>

Var. = number of variables, Bin. = number of binary variables, Cons. = number of constraints, Nonz. = number of nonzero coefficients.
The solution results are presented in Table 1. Table 1 indicates that for the cost-based objective (model EC) the cheapest supplier \(i=7\) is selected only, for the service level objective (model ES), the total demand for parts is allocated among the three most reliable and most expensive suppliers \(i=1,2,3\) and for the equitable solution (model ECS) the supply portfolio contains both one reliable and expensive supplier \(i=2\) and two low-cost and unreliable suppliers \(i=6,7\). As an illustrative example, Fig.2 presents the demand for products and the expected production schedules for the optimal cost, service level and for the equitably efficient solution. In general, the service level-based solution, when no cost components are included in the objective function, better meets the customer demand, with the smallest fraction of unfulfilled demand. In addition, the expected production approximately follows the demand pattern.

The computational experiments were performed using the AMPL language and the CPLEX 12.5 solver on a MacBookPro laptop with Intel Core i7 processor running at 2.8GHz and with 16GB RAM. The solver was capable of finding proven optimal solution for all examples with CPU time ranging from several seconds to several hours.

5. CONCLUSIONS

The combinatorial stochastic optimization problem of equitably efficient minimization of expected cost and maximization of expected service level in the presence of supply chain disruption risks has been formulated as a mixed integer program with the ordered weighted averaging aggregation of the two objective functions. The equitably efficient solution (the supply portfolio and the schedule of customer orders) aims at achieving the normalized expected cost and service level values as much close to each other as possible. The computational experiments have indicated that the equitably efficient solutions combine high-cost and reliable suppliers with low-cost and unreliable suppliers. In addition, nearly perfect equity solutions are frequently found, which indicates that the obtained solutions are also the lexicographic minimax optimal solutions as well as the Pareto-optimal solutions, see [3].

Acknowledgments

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6. REFERENCES

Appendix

\[ P_s^* = \begin{cases} 
(1 - p^r) \prod_{i \in I_r} \prod_{i \in I \setminus I_s, P_i} (1 - p_i) \prod_{i \in I \setminus I_s, P_i} & \text{if } I^r \cap I_s \neq \emptyset \\
 p^r + (1 - p^r) \prod_{i \in I_r} P_i & \text{if } I^r \cap I_s = \emptyset 
\end{cases} \]

(1)

\[ E_1 = (\sum_{i \in I} e_i u_i + \sum_{S \in S} P_s \sum_{i \in I_s} A_{iS} u_i) + \sum_{j \in J} \sum_{i \in T, i \in S} g_j b_j (t - d_j) v_{st}^j + \sum_{j \in J, t \in T} h_j b_j (1 - \sum_{i \in T} v_{st}^j))/B \]

(2)

\[ E_2 = \sum_{j \in J} \sum_{i \in T, t \leq d_j} \sum_{s \in S} P_s v_{st}^j/n \]

(3)

\[ f_1 = (\sum_{i \in I} e_i u_i + \sum_{S \in S} P_s \sum_{i \in I_s} A_{iS} u_i) + \sum_{j \in J} \sum_{i \in T, i \in S} g_j b_j (t - d_j) v_{st}^j + \sum_{j \in J} h_j b_j (1 - \sum_{i \in T} v_{st}^j))/B - E_1)/E_1 \]

(4)

\[ f_2 = \frac{E_2 - \sum_{j \in J} \sum_{i \in T, t \leq d_j} \sum_{s \in S} P_s v_{st}^j/n}{E_2 - E_1} \]

(5)

\[ \sum_{l=1}^{2} (\lambda_l + \sum_{k=1}^{2} \delta_{kl}) \]

(6)

\[ \lambda_l + \delta_{kl} \geq f_{kl} ; k, l = 1, 2 \]

(7)

\[ \sum_{i \in I} u_i = 1 \]

(8)

\[ u_i \leq u_i; i \in I \]

(9)

\[ \sum_{i \in I} v_{jt}^j \leq 1; j \in J, s \in S \]

(10)

\[ \sum_{j \in J} \sum_{r \in T, r \leq s} a_j b_j v_{jt}^j \leq A \sum_{i \in I_s, i \in S} w_i; t \in T, s \in S \]

(11)

\[ \sum_{j \in J} \sum_{i \in I_\tau, i \in S} a_j b_j v_{jt}^j \leq A \sum_{i \in I_s} w_i; s \in S \]

(12)

\[ \sum_{j \in J} b_j c_j v_{jt}^j \leq C_t; t \in T, s \in S \]

(13)

\[ \delta_{kl} \geq 0; k, l = 1, 2 \]

(14)

\[ u_i \in \{0, 1\}; i \in I \]

(15)

\[ v_{jt}^j \in \{0, 1\}; j \in J, t \in T, s \in S \]

(16)

\[ w_i \in [0, 1]; i \in I \]

(17)
INDEX TO EVALUATE THE ENVIRONMENTAL PERFORMANCE OF LOAD TRANSPORTATION MODE

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Abstract

The objective of this work is to present a procedure to obtain an index representing the environmental performance of a load transportation mode in order to have an instrument to guide decision-making processes regarding the choice of a sustainable mode for load transportation. The proposed index will be derived from the integration of several indicators related to different environmental aspects that could be damaged by diverse activities performed. This integration will be achieved using fuzzy logic and a neurofuzzy architecture. This index will assist enterprises when planning a sustainable load transportation service, environmental agencies in controlling such a service and the society preserving the environment and insuring quality of life.

Keywords: environmental performance of load transportation, fuzzy logic in environmental performance, sustainable transportation mode.

1. INTRODUCTION AND OBJECTIVE

Load transportation systems are essential for any country’s economy. Without them, products would not arrive to consumers, industries would not have access to raw materials and would be unable to dispose their production (ERHART et al, 2006). However, in the different phases of a transportation project, the constituents of the environment are negatively impacted in different degrees, depending on the type and size of the transportation project that is being implemented, as well as on the environmental characteristics of the region in which it will be inserted (FOGLIATTI et al, 2004).

Therefore, entrepreneurs should be aware to ensure the use of a transportation system in a sustainable way with the smallest possible negative consequences for the environment, having the need to monitor and control the inherent activities defining and measuring parameters that represent the quality of the environment. The objective of this paper is to present a procedure developed to obtain an index that assesses the environmental performance of the operation of a load transport system. This index will help load transport companies to sustainably plan their services, environmental agencies in their control of cargo transportation and the society with the environment preservation ensuring higher quality of life and will result from the integration of a set of pre – selected indicators representing the environmental damage that the various modes of load transportation may cause. This integration of indicators will be obtained from the use of fuzzy logic, as this is a tool that allows to translate qualitative and vague verbal expressions into numerical values, using an aggregation procedure that compares all option with a single criterion, thus reducing partial points of view.

2. THEORETICAL FRAME

CRUZ (2004), PAIVA (2004) and DINIZ (2007) proposed Environmental Management Systems for the operation of Rail and Road cargo transportation systems and for fluvial work, respectively, all according ISO 14001, proposing environmental indicators as a support tool for management.
RIBEIRO (2005) and BADANHAN (2001) proposed in their works environmental and transport indicators as instruments for the environmental management in the assessment of the air quality and indicators and standards of environmental quality to standardize the environmental control processes in a work of pipelines, respectively.

According to LOUREIRO (2005) indices are the result of the combination of several variables or parameters in a unique value, assuming a relative weight for each index component, while LUZ et al (2006) understand the index as the top of an informational pyramid, in whose base there is the primary field data of various natures and in the middle the indicators that capture and communicate about the complex object being studied.

BRAGA et al (1995) apud SILVA (2005), define the fuzzy logic as an attempt to approach the precision, characteristic of the mathematics, to the inherent imprecision of the real world, and it was born from the desire to better understand the mental process of reasoning. SHAW and SIMÔES (2001), in the same line of reasoning, argue that fuzzy logic provides a method to translate verbal, vague, imprecise and qualitative expressions, common in human communication in an understandable form for computers.


3. FUZZY LOGIC AND NEURO-FUZZY SYSTEM

A typical fuzzy system consists of a base of rules, of pertinent functions and of inference procedures. The determination of the shape and the values of the pertinent functions can be done by different processes or techniques with employee experts, users, or observations of the variables behavior, using intuitive reasoning or based upon algorithms or logic operations. Each rule has associated an individual weighting factor, called Certainty Factor (CF) or weight, which represents the importance of the rule in relation to the other rules of the rule base. With the inference rules and their certainty factors degrees of certainty are determined (GdC) using appropriated techniques as the one proposed by Ebrahim Mamdani in 1975.

The defuzzyfication process occurs after the fuzzy inference and consists in the transformation of a linguistic vector to a numerical result useful to compare results from several options or when ordering them. There are several methods of defuzzyfication, being the Maximum Center the most used (von Altrock, 1995 apud Cury, 1999).

Artificial neural networks are structures of parallel and distributed processing, which use many simple units, which are strongly interconnected forming networks of different types. These units are arranged in one or more interconnected layers, and are associated to numerical weights that store the network knowledge. Such knowledge is obtained through a learning process that modifies those weights.

Neural networks are able to copy the way the human brain treats information, processing numerical information and having learning potential, while fuzzy logic seeks to reproduce the process of the human decision making process, using natural language, i.e. linguistics terms. The combination of these two tools results in the neuro-fuzzy technology.

4. PROPOSED PROCEDURE

To evaluate the environmental performance of the Operation of a Cargo Transportation System (OSTC) all potential negative environmental impacts to be generated by each transportation mode should be measured to obtain an overall value for each mode, thus facilitating the comparison between them and helping in decision-making process related to the most environmentally friendly one.

The proposed procedure for creating a sustainability index for the OSTC follows the steps presented below:

1. Characterization of the operation of the cargo transportation system (OSTC),
2. Definition of the activities of the OSTC and its associated negative environmental impacts,
3. Selection of Environmental Indicators and
4. Determination of the index through the fuzzy logic which comprehends the fuzzyfication and defuzzyfication processes as well as the inference one and the preparation of the neurofuzzy network architecture.

**Step 1: Characterization of the OSTC**

In this step the structures and the related processes used by the mode in analysis should be characterized (vehicle, routes, intersections, signage and layout including all kind of dimensions, terminals, maintenance offices, characterization of the nearby area, kind of cargo and the related processes of cargo loading, unloading and control).

**Step 2: Definition of activities of the OSTC and associated negative environmental impacts**

In this step the various activities performed to operate each mode should be described to deduce their potentiality to provoke negative environmental impacts, which should be presented and described.

**Step 3: Definition of the indicators**

With the information from the previous steps the input variables are obtained. When these are combined or aggregated, they produce the indicators that should be controlled to avoid or mitigate the environmental degradation to be provoked in the physical, biotic and anthropic means and particularly in the climate of the area under analysis.

The indicators proposed in this work are: the Indicator of Pollution as a function of the Indicators of the Quality of the Physical Mean-IQMP, of the Quality of the Biotic Mean-IQMB, of the Quality of the Anthropic Mean-IQMA and of the Climate Disorders-ICD due to the CO2 emissions. These indicators represent the level of negative impacts that the operation of the studied system can generate in the physical, biotic and anthropic fields as well as the level of risk associated with the passage under analysis and action on climate gas emissions in the atmosphere.

For the physical mean, the air, water and soil qualities should be measured. The elements that contribute for the different levels of these kinds of qualities are noise, dust, odors and spill of oil from vehicles and equipment used for cargo transportation. For the biotic mean, reduction of species of plants and of animals provoked by the studied mode, contribute to the mean quality. To represent the anthropic quality, human health level, risks of accidents and modifications in land use should be accounted for. And the element that could bring disorders in the climate of the region under analysis is the CO2 emissions caused by vehicles and equipment used in the operation.

**Step 4: a) Structural diagrams**

Having selected all the components that should be taken care to obtain the desired qualities, structural diagrams should be built. In Figures 1, 2, 3 and 4 the structural diagrams for the proposed indicators are presented.

![IQMP structural diagram](image)
Step 4: b) Fuzzyfication process

The linguistic expression for each variable can be obtained through survey by field measurements, by projections or through estimative. According to several researchers the definition of the fuzzy sets is the most critical step in building a fuzzy system as it determines the correspondence between the input variables and their correspondent linguistic concepts. However, has been experimentally shown that fuzzy systems perform well even when the shapes of their sets are not precisely drawn.

Step 4: c) Preparation of the neurofuzzy network architecture

To facilitate the analysis of the operation of a freight transportation mode, a neural network architecture should be built aggregating few variables in each node to apply the inference process as well as in the establishment of the rule base, allowing a better definition of the linguistic terms as well as in the allocation of the CF to each rule. In the proposed process, the aggregation of the four structural diagrams shown in Figures 1, 2, 3 and 4 will provide the General Environmental Performance Index -IGDA.

Step 4: d) Inference process

Once the fuzzyfication is done, the inference process is applied relate variables using the rule base previously constructed by specialists.
Step 4: e) Defuzzyfication process
To make comparisons among different modes of freight transportation, it is necessary to apply the process of defuzzyfication, that is, to transform the linguistic vector into a numerical result.

5. FINAL CONSIDERATIONS
The operation of the different modes of freight transportation generates negative impacts when it is performed without due care, affecting biotic, physical and anthropic components of the environment in different levels depending on the environmental characteristics of the region where they operate. Being so, the selection of the less adverse mode of transportation is necessary since the regions’ quality of life depends on it.

The advantages of the proposed procedure are several, for example: the participation of specialists in the process facilitates the assessment of the levels of damage that the different activities of the operations related to each mode of freight transportation can cause to the environment; qualitative and quantitative variables can easily be controlled; working with this kind of structure brings great flexibility and it makes it possible to insert or withdraw variables; it also facilitates the construction of scenarios that makes it easy to evaluate the sensitivity of the procedure; the weights assigned to each variable can be easily modified according to the purpose of the evaluation and it is easy to implement in an electronic spread sheet. The main advantage related to this procedure is the fact that it is an important tool for the decision making process for the different sectors involved in the freight transportation system. This index is important for the government to facilitate his task in supervising this service, to the enterprisers that offers the service in avoiding the payment of significant fines when the law is not obeyed and to the society by promoting a higher quality of life.

Some limits and difficulties related to the proposed procedure can be highlighted: the need to constraint the number of the linguistic variables in each block of inference to reduce the number of rules derived from their combination and the need to incorporate experience and expertise in the decision-making process to help in generating fuzzy sets, in developing the rule base and in the selection of weights for each variable.

6. REFERENCES


A CLASSIFICATION FRAMEWORK FOR SUPPLY CHAIN FORECASTING LITERATURE

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Abstract
Forecasting in Supply Chain Management (SCM) is an important yet underestimated research topic. Over the past years numerous methods and concepts have been developed, tested and deployed. In this paper we present a classification framework for the SC Forecasting literature using eight criteria, namely focus, approach, method triangulation, data generation, range, timeline, theoretical background, and target group. Additionally, we present examples for the respective criteria and summarize the major findings. This state-of-the-art review paper is targeted toward both researchers and industry experts who want to get an overview of the goals of contemporary SC Forecasting research.

Keywords: Forecasting, Forecasting Models, Supply Chain Forecasting, Supply Chain Management

1. INTRODUCTION
Forecasting is an important and well-established research topic in economics as well as in business. Not only exists a plethora of literature which deals with various aspects of forecasting and prediction, but even highly specialized journals (e.g. Long Range Planning, Journal of Forecasting, Journal of Business Forecasting, International Journal of Forecasting, Foresight: The International Journal of Applied Forecasting) and conferences (e.g. Supply Chain Forecasting and Planning Conference, Sales & Operations Planning (S&OP) Conference, Workshop on Industry & Practices for Forecasting) exclusively focus on that area. Notwithstanding the long tradition of this research stream, Datta et al. [1] state that “Forecasting is an underestimated field of research in Supply Chain Management” (SCM) (p.187). At first sight, this seems surprising, given the high importance of forecasting for an effective and efficient supply chain. For instance, one of the most important phenomena in business, the so-called Bullwhip (Forrester) effect, was discovered more than 50 years ago [2]. Today scholarly papers still deal with this highly complex subject [3] [4]. We found four major reasons for the enduring importance of SC Forecasting on which we will elaborate in the following subsections.

1.1 Increasing Market Volatility
The financial crisis of 2007/08, which was followed by a global recession that affected the entire world economy, has caused many companies to rethink their overall business strategies. Following the economic downturn, a general awareness now exists that increasingly complex international business networks lead to dependencies on business partners and a greater-than-ever vulnerability to market fluctuations triggered by political crises, natural disasters and economic cycles [5]. Current research and political indicators point towards an ongoing market volatility in the future [6], which tend to make corporate forecasting and planning crucial yet increasingly difficult.

1.2 Methodological Developments
New and innovative methods take time to diffuse from formal to applied science and finally to the industry. Frequently, established methods are modified in order to fit a prevalent problem. Datta et al. [7], for example, illustrate how to adapt an advanced forecasting technique, GARCH (i.e. Generalized Autoregressive Conditional Heteroskedasticity) with the goal of improving it into a flexible decision support tool. Those models are based on ARCH models, which were originally developed by Nobel prize laureate Robert Engle [8] decades ago. Datta et al. [7] further refine them by adding vector auto regression (VAR)
methodology and model volatility for a vector rather than a single series. They suggest to call the proposed model VAR-MGARCH and conclude that “in one isolated experiment [...] the model provided a forecast that was appreciably closer to the observed or realized value” (p. 1469). However, they also stress the need for further methodological refinement: “This observation is immature. [...] Several more experiments with rigorous controls must be performed before this result may be even considered to offer ‘preliminary’ evidence that the GARCH type model proposed in this paper may represent an advanced tool” (p. 1469). This is but one of many examples in which existing methods are altered in order to fit the demand of modern SCM.

1.3 Big Data

In a current issue of the Journal of Business Logistics (JBL), Waller and Fawcett [9] describe data science, predictive analysis and big data as “a revolution that will transform supply chain design and management” (p. 77). They show that, in spite of being often named a buzzword, big data holds a lot of potential for those companies which understand how to capitalize on it. The opportunities for organizations to gain valuable information from big datasets are simply too attractive to ignore them. Furthermore, as is the case with most hypes, numerous companies are afraid of losing market share to competitors who capitalize on the “first mover advantage”. Modern technology has made it possible to easily gather data in hitherto unimaginable quantities. Quite naturally, in many cases these data contain valuable information which can be used for extracting meaningful forecasting information that helps to generate agile supply chains [10].

1.4 Supply Chain Focus

Although a significant amount of papers exists which exclusively deals with forecasting in the supply chain, the majority of published research either focuses on methodological issues or has a different kind of operational focus. Hence, a huge untapped potential of forecasting knowledge exists, which allows SC researchers to simply transfer existing know-how in order to tackle problems specifically pertaining to supply chains. This is of crucial importance, since the overall importance of SC Forecasting is constantly growing [11].

The remainder of this paper is organized as follows: In section 2 we will briefly elaborate on the methodology we used for this research, followed by the presentation and discussion of our classification framework in section 3. Finally, we summarize our findings, highlight implications and options for further research and also mention several limitations.

2. METHODOLOGY

In this conceptual research-in-progress paper we followed the procedure suggested by Tranfield et al. [12] for conducting a systematic literature review. We first identified relevant keywords related to SC Forecasting and used the scholarly databases “ProQuest” and “EBSCO” as a starting point. The literature review was carried out from September 2013 until March 2014 and was constantly refined by including articles being cited in the analyzed papers or which we found via Internet search (e.g. by using Google Scholar). We finally ended up with a total of 92 papers which had both a focus on supply chains as well as forecasting and which we deemed relevant for the study at hand. In the first phase we classified each paper according to its main research goal. Next, we created various categories suitable to further categorize the papers. If a paper did not fit into one of our categories, we revised and extended our framework. In line with the qualitative and explorative nature of this research, we did not strive to categorize all papers exhaustively and did not provide any descriptive data pertaining to the absolute number of papers within a specific category, but rather used the publications in order to create a sufficient number of categories in our framework. In the following section we will not only introduce the framework itself, but also briefly discuss various examples of papers in order to illustrate the meaning of the respective categories.

3. SCM FORECASTING IN THE LITERATURE: A CLASSIFICATION FRAMEWORK

During the classification process a total of 8 different categories emerged. It has to be noticed that this framework is neither fully exhaustive nor mutually exclusive, but its main purpose is rather to highlight the various existing goals of contemporary SC Forecasting research. We will provide one or more examples in each category for illustration purposes.
3.1 Focus
A lot of published research in academic literature focuses on developing and refining methods. Apart from the previously mentioned paper from Datta et al. [7], another example stems from Ferbar et al. [13], who utilize the theory of wavelets in order to create a wavelet denoising model which they find to be superior to the commonly used exponential smoothing method. A second stream of research focuses on the classification of existing methods. Armstrong [14], for example, presents a selection tree for various forecasting methods, whose choice depends on criteria such as available data, expected changes, available expertise, similar cases and domain knowledge. This tree may be used to select the best suited method for a given problem with various characteristics. Finally, scholarly papers exist which compare methods and give recommendations on how to choose the most appropriate one. Acar and Gardner [15], for example, select the most appropriate method based on operational performance in a real supply chain. They compare various exponential smoothing methods and base their final choice on tradeoff curves between total costs and customer service.

3.2 Approach
In academic literature, quantitative approaches are prevalent, as is shown by the meta-study from Fildes et al. [16] who analyzed a total of 558 publications in forecasting research. 27.2% of the papers used univariate methods, 21.5% causal and multivariate methods and 13.4% computer-intensive methods such as non-linear statistical methods and neural nets. Only in 8.2% of the cases judgment, i.e. a qualitative approach, was used. The authors also categorized 879 articles from operational research journals and found a similar dominance of quantitative methods with only 8.5% of the papers under investigation using judgment. This coincides with our findings that the vast majority of the scholarly papers relies on quantitative data. However, we also found examples for papers which combine qualitative and quantitative approaches [17] [18], or which solely rely on a qualitative approach. An example of the latter category comes from McCarty and Golicic [19], who use depth interviews with executives in three firms in order to come up with seven guidelines for implementing interfirm collaborative forecasting. As far as quantitative research is concerned, the majority of publications deals with the development, testing and refinement of forecasting techniques. However, we also found evidence for survey-based research. Nakano [20], for example, administered a survey among 65 Japanese manufacturers and used confirmatory factor analysis in order to examine the perceived impact of internal and external collaborative forecasting and planning on logistics and production performance.

3.3 Method Triangulation
The aforementioned study from Fildes et al. [16] also lists the usage of method triangulation, i.e. the combination of various methods in order to study a situation or phenomenon. 3.8% of the forecasting and 6.1% of the operational research publications actually applied method triangulation, indicating that the vast majority of publications use a single method only. Notable exemptions include Caniato et al. [17] who integrate quantitative and qualitative approaches to improve demand forecasting in the cement industry and who report improved forecasting accuracy as well as increased knowledge within the organization. The second example stems from Forge [18], who uses a qualitative forecast derived from a scenario for a quantitative projection. Although not exclusively focused on SCM, his approach may be used for all studies which need to simultaneously take into account socio-economic, technological and market developments. Third, Goodwin and Fildes [21] report that in the industry statistical forecasts are frequently adjusted using management judgment. They differentiate between large adjustments, which tend to improve accuracy, and small ones, which often turned out to be a waste of time.

3.4 Data Generation
Another distinctive feature which we observed in the literature is the type of data generation. Researchers have a choice between collecting real world data from companies [22] and using some kind of Monte Carlo experiment in order to obtain the required distribution of an unknown probabilistic entity [23]. We observed the latter procedure mainly in the context of testing new methods. In some cases the authors split an existing real world data set in order to create a model and use the remaining data for testing purposes [24].
3.5 Range

Collaborative planning, forecasting and replenishment (CPFR), i.e. the joint planning of key supply chain activities, has gained significant attention in recent years. Previous research has shown that CPFR yields numerous positive results, such as the need to innovate and strong relationships between business partners [25]. Several authors therefore consider the potential impact of decisions that go beyond company boundaries. Aviv [26], for example, presents a time-series framework for supply chain inventory management which takes into account the benefits of various types of information-sharing agreements between supply chain members. He presents a methodology which allows for the investigation of the benefits of various types of information-sharing options, such as sharing subsets of demand-related information or sharing information in one direction of the channel. Acar and Gardner [15] discuss the case of a global manufacturer which owns plants in America, Europe and Asia. Their paper is about forecasting method selection in a real supply chain and they conclude that “forecasting must be evaluated at the aggregate level […] for the entire supply chain” (p. 847).

3.6 Timeline

We found a large number of publications investigating changes over time, which is common in forecasting research. Although it is possible that these papers are purely conceptual and do not use data, as is the case with Giloni et al. [27] who investigate the problem of demand propagation in multi-stage supply chain and demonstrate the benefits of information sharing, many of the papers we found rely on actual time series data [30].

3.7 Theoretical Background

The importance of theory varies between scholarly disciplines, as does its purpose and usage [28]. We found that most research on SC Forecasting focuses on solving specific operational problems and does not refer to a specific underlying theoretical background. Notable exceptions include Stapleton et al. [29] who discuss in their conceptual paper the applicability of chaos theory principles to selected supply chain functions and who conclude that chaos theory bears some potential to help explain unpredictability within nonlinear systems. Ferbar et al. [13] use a mathematical approach when they apply the theory of wavelets in order to denoise signals.

3.8 Target Group

We found that the publication outlet mainly determines the respective target group (researchers vs. practitioners), which is usually the case in all kinds of academic and non-academic communities. We were therefore especially interested in publications which might serve as a bridge between these groups, i.e. which might be well-suited to transfer cutting-edge knowledge into the industry. We found several examples, e.g. in the Journal of Business Forecasting Methods & Systems, such as the papers from Peterson [31], who reports on the supply chain integration efforts of the Bayer HealthCare Division and how they improved forecasting by reducing bias, and Picksley and Brentnall [32] who describe how Bayesian modeling might help to enhance supply chain forecasting and planning. A similar outlet is the Journal of Business Forecasting, in which Khadar [33], for example, describes how a vendor inventory management program helped to create visibility in the supply chain and let to improved forecasting. Occasionally, relevant papers were published in high-impact journals such as Harvard Business Review (HBR), as is evidenced by the publication from Fisher et al. [34] who illustrate how companies manage to cope with uncertain demand.

### Table 1 – SCM Forecasting Literature Framework

<table>
<thead>
<tr>
<th>Category</th>
<th>Methodology</th>
<th>vs.</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Methodology</td>
<td>vs.</td>
<td>Application</td>
</tr>
<tr>
<td>Approach</td>
<td>Quantitative</td>
<td>vs.</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Method Triangulation</td>
<td>Yes</td>
<td>vs.</td>
<td>No</td>
</tr>
<tr>
<td>Data Generation</td>
<td>Real World Data</td>
<td>vs.</td>
<td>Simulation</td>
</tr>
<tr>
<td>Range</td>
<td>Single Location</td>
<td>vs.</td>
<td>Chain</td>
</tr>
</tbody>
</table>
Table 1 summarizes the eight major categories of our framework. Most papers can be classified according to all of the criteria, some of which overlap.

4. CONCLUSIONS AND LIMITATIONS

Supply Chain Forecasting is a topic which is of utmost importance to both practitioners and academics. Numerous papers in this area have been published over the past decades, and new methods and concepts are constantly being developed, tested and refined. In this review paper we present a framework which may be used for classifying existing research according to its main goal. We differentiate between eight categories (focus, approach, method triangulation, data generation, range, timeline, theoretical background, target group) and provide several examples in order to illustrate the respective categories. We show that numerous papers exist which shed light on the intricate subject of SC Forecasting from different angles. Authors use a wide variety of methodological approaches, data generation methods and research designs in order to make useful contributions for their respective target groups.

This paper is research in progress and part of an extensive SC Forecasting project. Therefore, several limitations exist. First, our framework needs to be refined with further categories and a more detailed distinction between them. Rather than having only two options in each category, more choices might be appropriate. Second, we suggest to find categories which are mutually exclusive and collectively exhaustive, and, third, a comprehensive quantitative study is needed which shows the distribution of papers in each category.

Finally, we also want to highlight opportunities for further research. Our preliminary results already suggest potential research gaps, such as the significant time lag of knowledge diffusion into the industry. We found a huge number of cutting-edge research papers, but there is strong indication that the actual application of novel research findings in the industry frequently has a significant delay. Future studies might enhance our framework and use the results in order to systematically identify research gaps in the area of SC Forecasting.

5. REFERENCES

Supply Chain Forecasting is a topic which is of utmost importance to both practitioners and academics. It is constantly being developed, tested, and refined. In this review paper, we present a framework which may be appropriate. Second, we suggest finding categories which are mutually exclusive and collectively exhaustive, distinguishing between them. Rather than having only two options in each category, more choices might be possible.

This paper is research in progress and part of an extensive Supply Chain Forecasting project. Therefore, several limitations exist. First, our framework needs to be refined with further categories and a more detailed theoretical background. Second, we suggest finding categories which are mutually exclusive and collectively exhaustive, distinguishing between them. Rather than having only two options in each category, more choices might be possible.

Finally, we also want to highlight opportunities for further research. Our preliminary results already suggest that further research is needed.
PROCEDURE MODEL FOR AN UNERRING
WAREHOUSE PLANNING FACING STRATEGIC
AND LOGISTICAL TARGETS

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Abstract
Unerring stock keeping has a direct impact on the management of a warehouse and has to fit to strategic
business objectives. Also the infrastructure of a warehouse has to be consistent with the objective targets in
the fields of logistics too. This paper identifies and explains 8 phases for an unerring implementation of a
new warehouse. The surplus of this paper is defined through the definition of the gap between the strategic
business objectives and the targets for the field of logistics, which have a direct impact on the process model
for the construction and planning of warehouses.

Keywords: warehouse planning, unerring stock keeping, material flow, warehouse performance

1. INTRODUCTION
Independent from the branches of industry, companies have to deal with strategic implications in the scope
of logistics and stock keeping. Meanwhile companies already know about the cost of stock keeping and its
effects on customer service levels. Stock holding may gain economic advantages in competition for example.
The key to success is defined through the relation between the costs of stock and the thereby emerging
customer service levels.

To reach the optimum in this area of conflict it is necessary to define what unerring stock keeping means for
a warehouse, what the impacts on the management of warehouses are and how to implement this objective
target in the planning process of a new warehouse.

Based on this consolidated findings it is possible to plan and design a warehouse to reach these logistic
targets. The authors provide in this scientific paper an approach for a step by step procedure model for
planning and building a new warehouse. This also includes the use of methods to increase the efficiency of
integrated logistic processes.

2. UNNERING STOCK KEEPING
Each company has a number of objectives that are formulated for either the whole company or for individual
areas like the purchasing department, production, sales department, etc.. Derived from the overall corporate
objectives such as liquidity and profits, functional objectives are defined for each strategic business unit.
These overall corporate company's objectives can be both, material and immaterial. Superordinate goals are
further broken down and given to the functional areas as instrumental goals. The very broad corporate
objectives are refined with each level. [1]
The operative instrumental goals provide concrete action criteria for the planning, management and control of operational processes within the business. Targets are getting more concrete with each step top-down until they reach the lowest level, the operative goals which are clearly defined treatment instructions.

Like all other departments of a company (e.g. production or finance) also the logistic department has to contribute to the overall efficiency of the company [3], of course.

The authors identify three main components of logistic performance which have a direct impact on the overall company’s efficiency: objective fulfillment, quality assurance and cost reduction.

It should be noted that the three components of logistic performance cannot be considered separately because they influence each other and are interdependent. Specific objectives, e.g. the throughput time cannot be clearly assigned to one component because it is defined through the interaction of all three components. To understand the relation between the three components it requires a holistic and customer-orientated view of the total logistic costs of the supply chain and the overall logistics performance offered to the customer. [5]

UNERRING DELIVERY SERVICE LEVEL

Unerring stock keeping means the fulfillment of the required service level demanded by the customer. By merging the three most important customer oriented performance figures (stock availability, quality of consignment and the adherence of delivery dates) the performance and quality of a warehouse can be measured with ease.
The delivery service level provides an accurate indicator how unerring a warehouse can fulfill customer’s requirements. The delivery service level is often implemented as a KPI (Key Performance Indicator), agreed with both, customers and suppliers within a contract.

### 3. 8-STEP-PROCEDURE MODEL FOR WAREHOUSE PLANNING

In order to meet the conditions for achieving the desired delivery service level a gradual process model for warehouse planning will be defined.

#### 3.1 Situation definition

The trigger for planning a new warehouse can result from company internal factors (endorsement extension, increase in production volume, rationalization, new production processes) as well as from external influential factors (safety regulations, procurement and sales market changes) [6].

Martin distinguishes three types of warehouse planning according to the following criteria:

**New-planning**  
If the optimization potential is exhausted within an existing warehouse and if the given storage capacity is exhausted too, the need for a new, strategic warehouse is given. It is important to ensure that potential future extensions are to be stipulated. The objective within the planning process of a new warehouse is mostly derived from the strategic objectives of a company and is associated with high investments.

**Expansion planning**  
Expansions of warehouses require a high level of design quality since in this case the design must be elaborated under the given restrictions (limited infrastructure, land use, safety concepts etc.).

**Re-planning**  
As with the expansion planning, given restrictions must be considered. The main focus of re-planning warehouses is to qualitatively adopt existing restrictions to changing conditions and demands of the market.

#### 3.2 Analysis of the initial situation

The analysis of the initial situation includes activities such as collection, preparing and analyzing of relevant data and indicators as well as of the entire infrastructure.

It forms the basis for the extrapolation to the plan-situation and consists of the following basic elements:

**Analysis of infrastructure**  
The aim of the analysis of the infrastructure is to document the given restrictions which influence the layout later on (storage areas, internal transport routes, possible extensions, energy and water supply, etc.).

**Analysis of logistics technology used**  
Data capture of existing logistics technology as well as the documentation of related software functionalities to support the warehouse processes are important parts of the analysis of the initial situation except the project is about building a new warehouse. Existing technologies can be further developed or used as before to support warehouse operations (receiving, put away, picking, etc.).

**Process descriptions**  
A comprehensive process description provides an accurate understanding of the complete warehouse processes from the intake to the final loading of goods at the dispatch area.
Material flow and data analysis

The objective of the material flow and data analysis is to underpin the process descriptions with quantitative figures and performance data. Due to the complexity of material flow and data analyzes, the procedure shown in the figure below is recommended.

Table 2 – material flow and data analysis

Analysis of the given restrictions

The first part of the analysis of the given restrictions, the structural ones, were already considered in the infrastructure analysis. In addition there are external restrictions concerning safety requirements, environmental conditions, competition, management guidelines, etc. which must be considered.

3.3 Extrapolation to plan situation

The primary driver for the dimensioning of a warehouse is the forecast of the future sales volume derived from the strategic goals of a company, including the related delivery service level. Based on this, the purchasing planning, production planning and the inventory planning take place in terms of capacity and resources. These inter-influencing forecasts need to be consolidated within the financial-, cost- and profit planning process. [7]

3.4 Design

Based on the projected plan situation in respect to the needed performance and dimension of a warehouse, layouts, required capacity and process scenarios can be designed. The strategic goals and also the defined restrictions represent the framework for the design process.
A proper and consistent material flow concept represents the highest importance for an efficient warehouse. Therefore it is significant to start the design process with the modelling of potential scenarios.

It is important to focus not only on the physical material flow alone but also to combine this planning with the related information flows, the flows of staff and the flow of energy within a warehouse. Especially the flow of energy is important because it includes the supply of the individual operating components with required energy types (gas, water, electricity, steam, compressed air, etc.) and required quantities [8].

For the design of flow of materials the application of the principles of route optimization can be an essential success factor to raise efficiencies in warehouse processes.

One danger of logistical planning is to choose a particular technical solution already at the beginning, which prevents from analyzing different material flow alternatives and different warehouse layouts in general.

The overall target of designing a warehouse is on the one hand defined through desired performances and capacities and on the other hand by the target to minimize initial and the operational costs. The following design principles shall be helpful in practical projects:

- avoid hand transports and mechanize or atomize and utilize transports
- consider future requirements and strive for flexibility of the solution
- increase the area and space utilization
- avoid intersections and oncoming traffic in the material flow
- establish transport units according to the principle: manufacturing unit = transport unit = storage unit
- apply short distances, high transport speed and utilize conveyances
- if possible, take advantage of gravity and consider upstream and downstream material flow lines. [9]

### 3.5 Evaluation and scenario decision

To approve the final layout and dimension of the new warehouse it is necessary to evaluate the defined solution proposals and scenarios. Therefore utility analysis or a simple comparison of different layouts provides a profound basis to select the solution that comes closest to the weighted requirement criteria.

A final solution represents a proposed decision, which must be adopted by the management of the enterprise. Possible evaluation criteria can be:

- Flexibility, adaptation to fluctuations in production
- Allocation of storage to manufacturing and the degree of mechanization, automation
- Processing times of work pieces, clarity, susceptibility
- Investment and operating costs (e.g.: staffing needs)
- System efficiency (availability)
- Area, height, space and conveyance utilization as well as expansion possibilities. [10]

### 3.6 Detailed planning

On this last stage of planning, all preparations for the realization have to be finally prepared to ensure a smooth construction sequence. This includes for example:

- Checking and completing the technical data
- Setting up and testing of functional processes, e.g. by analytical methods or by simulation
3.7 Implementation
The phase of execution (implementation, construction sequence) of the project is no more a planning process, but has primarily functions like coordinating, monitoring and testing in terms of project management. In this phase the warehouse is going to be built (construction and installation of equipment and facilities).

3.8 Evaluation
It is not only after the design and detailed planning phase, but also after successful implementation of a new warehouse important to evaluate the performance and the capacity on the basis of the pre-defined criteria for an unerring stock keeping. A useful method therefore represents a static or dynamic simulation of order structures and material flows. A general statement, whether static or dynamic simulation is to be preferred cannot be made as this depends primarily on the complexity of the processes and the available resources (financial and personnel). However, a combination of the two simulation methods, for example a holistic static simulation in combination with a selective dynamic simulation for bottlenecks or critical elements can be very promising.

The description of the individual stages of planning in sequences should not obscure the fact that the process of planning a warehouse is an iterative process. The later a need for change in the planning process is detected, the more complex and usually more costly is the modification effort. [12]

With the takeover of the plant by the contracting authority with its own employees the project is completed. At this point of time also the risk is transferred to the operator of the new warehouse. [13]

4. CONCLUSION
In recent years the importance of logistics in business has increased significantly. However, the correlations of optimized warehouse design, intra-logistics systems and operational processes with the strategic corporate objectives are often still underestimated. How to identify such gaps was illustrated especially in the first main chapter of unerring stock keeping.

Starting with the analysis of a warehouse location and the definition of proposed inventory levels a static or dynamic simulation of throughput data affect not only the financial targets of a company, but also the corporate market position meaning the offered service levels.

Likewise, numerous points about supply chain management have been identified as criteria for unerring warehouse planning. In practice, new forms of business cooperation however gain steadily in importance and lead to increased demands in terms of flexibility in service levels. But such impacts on operational logistics are taken into account only in rare practical cases.

To sum up, the implementation of logistics in strategic business planning must be further strengthen. A comprehensive integration of the IT infrastructure in conjunction with deliberated warehouse processes is the basis for a high degree of responsiveness along the supply chain. Powerful intralogistics, logistics technology and the related flexibility to respond to changing market conditions is increasingly becoming the decisive competitive factor.

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GREEN SUPPLY CHAIN MANAGEMENT PERFORMANCE: A STUDY IN BRAZILIAN OIL AND GAS COMPANIES

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Abstract
The oil and gas industry in Brazil has become a very important sector for the country’s economy due to the discovery of new oil and gas reserves. Thousands of oil barrels produced or distributed have been spilled in the environment causing large damages that last for years. Green Supply Chain Management (GSCM) seeks to minimize the environmental impacts caused by industries’ logistics activities and processes. The aim of this paper is to present an exploratory study conducted in companies located in Brazil. The results are related to the application of theoretical indexes proposed to the oil and gas industry’s GSCM.

Keywords: green supply chain, oil and gas industry, performance indexes, exploratory study, Campos Basin

1. INTRODUCTION
The oil and gas industry in Brazil is a strategic sector for the Brazilian economy. According to [1], the oil and gas industry will receive an investment around US$ 180 billion dollars in the next three years, much more than other relevant industries. In 2012, Brazil produced more than 750 million of oil barrels, becoming the 13th world largest producer [2].

Most of the Brazilian oil and gas production is offshore, corresponding to about 91% of the total production. The Campos Basin in Rio de Janeiro State includes 81% of the total offshore production [2]. The oil and gas industry has become a very important sector in the last years mainly due to the discovery of new oil and gas reserves in pre-salt region. [3] presented some characteristics of the Campos Basin as well some logistics challenges to meet the future demands.

Logistics plays an important role in this industry. However, problems in logistics processes and activities may cause significant impacts in the environment. Some data shows that, despite the fact that the number of spills has decreased in the last 40 years, during the period 2010-2013 there were accidents in production and distribution. More than 20,000 tons of oil spilled in the environment [4]. In Brazil, in March 2013, there was a leakage of 4 thousand oil barrels in the Rio de Janeiro coast originated from a problem in the drilling rig perforation. The result was that the responsible company was fined in US 150 million dollars, so as to compensate environmental damages [5].

During the last years there has been an increase in concerns related to environment issues among people and companies in general, mainly related to industrial development. Also, there has been a focus on supply chain’s operational processes which led to a “greener” perspective of the activities and to the Green Supply Chain Management (GSCM) initiative [6]. As mentioned by [7], due to an increase in environmental awareness all over the world, the concept of Green Supply Chain Management has been highlighted. It can be defined as a way of integrating environmental thinking into Supply Chain Management.

As stated by [8], the Green Logistics and the GSCM seek to minimize the environmental impacts caused by the logistics activities and processes. In relation to the oil and gas industry, it is a relevant issue as the
environmental damages of the mentioned industry may last for decades, interfering not only in the affected areas but also the industry, the business partners and the region’s economy.

As stated by [9], many companies have failed to manage Green Supply Chain Management due to the difficulty in developing performance indexes that reflect the real and complete integration among all in the supply chain’s activities. In this sense, the mentioned authors argue that there is a need to establish appropriate indexes capable to measure the performance of industries’ GSCM.

As also claimed by [10], the development of performance indexes to measure how green a supply chain activity is represents a great challenge. However, it is an important issue, as it seems there cannot be found an integrated approach or a mechanism to measure, control and improve the environmental aspects of a supply chain as a whole. As asserted by [11], with the introduction of GSCM, the use of traditional indexes may not reflect the environmental impact of logistics activities. In this context, there is a need to develop indicators that may reflect the impact of operations and logistics activities on the environment.

The main purpose of this paper is to present some results related to the application of a set of theoretical indexes proposed to the oil and gas industry Green Supply Chain Management, through a study conducted in companies located in Campos Basin, in Rio de Janeiro state, Brazil. The research presented here is part of a larger study that focuses on the development of performance indexes specific to the oil and gas industry’s Green Supply Chain Management. It aims to allow the companies to evaluate and measure their logistics processes and activities so as to make them more sustainable and more environmentally friendly, as well as aggregating value to the whole chain and industry.

2. GREEN SUPPLY CHAIN MANAGEMENT (GSCM)

The environmental impact of diverse business activities has become an important issue during the last years mostly because of the increase of a greening thinking among people. This seems to be a result of legislation, new laws and regulations among the countries, as well as from marketing and ecological concerns of the consumers [12]. As shown by [7], the number of terms related to Green Supply Chain Management in published papers has been rising yearly.

The oil and gas industry also produces damages and impacts to the environment. As stated by [8], the main increasing environmental impact factors in logistics systems are: 1) fossil fuels consumption growth in diverse transport systems; 2) leakage of potentially toxic loads during transportation; and 3) contamination of storage systems by potentially toxic products.

According to [13], GSCM can be understood as an extension of the traditional supply chain management, considering the totality of immediate and casual effects of all products and processes in the environment. This chain contains all the elements of the traditional chain plus products recycling and packaging, reuse, and/or remanufacturing operations.

As highlighted by [7], GSCM is a field of implementation of the green thinking in all the segments of companies’ logistics and supply chain activities, such as green sourcing, green production, green logistics, green transportation, green warehousing and reverse logistics. Also included by [9], there can be found green procurement and acquisition, green marketing, green distribution and green material handling as GSCM activities.

The Green Supply Chain Management initiatives in activities such as acquisition, manufacturing, distribution and recycling have become a trend for the companies [12]. In this sense, we argue that GSCM can be seen as a relevant issue to the management of the supply chain worldwide, mainly to oil and gas industry, so as to diminish the environmental impacts of its current industrial processes and activities.

2.1 Oil and Gas Industry Green Supply Chain Management

GSCM can be seen as an ally to oil and gas industry business activities. This is due to the fact that it shows more environmental awareness by implementing more appropriate production processes, as well as environmentally friendly transportation, greener distribution, the purchasing of ISO certified suppliers and reverse logistics. As described by [14], oil and gas industry logistics operations impacts are more visible during transportation because the raw materials, supplies and the final products need to be displaced from the exploitation/drilling (onshore and offshore) and the production centers to the refining warehousing and to the distribution areas, until they reach the final consumer.
A theoretical model for the oil and gas industry GSCM has been proposed by [15]. The author stated that an oil and gas supply chain requires many activities, ranging from the prospection in production fields up to the distribution of the products to final consumers. Every activity plays an important role in the reduction of environmental damages. The oil and gas industry GSCM model used for this study was based on [8, 14, 16], as well as on the [15] model, including the reverse flows (reverse logistics) of recycling, reuse and remanufacturing materials, the proper disposal of materials and energy, and also materials consumption reduction. Activities such as green production, green transportation and distribution, green warehousing, green purchasing and acquisition, green packing and green marketing have been added to the GSCM model, too in this study. In this sense, the oil and gas industry Green Supply Chain Management model can be divided in three segments: 1) Upstream - the set of all the exploitation and production activities of oil and gas; 2) Midstream - which includes the refining activities, oil and gas processing; and 3) Downstream - which involves all activities, in addition the distribution and sale of oil derivatives and gas to the market. Transport between different stages from production to the consumer market should be revised pursuing the optimization of truck loads, routes and fuels, as well as the selection of a best modal in order to minimize the impact on the green value chain, as well as on the environment. It is also important to stress that suppliers should be integrated with the greener goals of the chain, focusing on environmental sustainability.

The Green Supply Chain Management model proposed in this study for the oil and gas industry shows the relationships between the different activities and operations and how they can interact and cooperate in the search for environmentally sustainable solutions. This model and the relations among these activities served as the support for the construction of the theoretical performance indexes proposed to the oil and gas industry Green Supply Chain Management.

2.2 Theoretical Performance Indexes for Oil and Gas Industry Green Supply Chain

Based on the above mentioned oil and gas industry GSCM and on some performance indexes presented by [9, 10, 11, 12, 17, 18] for GSCM, as well as on [15] study, we present a summary of the performance indexes that may help the oil and gas industries to evaluate their processes and logistics activities as follows:

a) Managing Internal Environment: The aim is to measure the managers’ level of commitment to GSCM activities and the level of support to logistics activities and to environmentally friendly processes. This includes cooperation instruments to improve the intra-company and inter-companies relationships in all activities and systems, so as to benefit the environment. Also, it seeks to understand the programs (ISO 14000 certification, internal audit, TQM), the management systems (frequency of environmental accidents; pollutant, waste, consumption and accidents reduction etc.), and the processes that may help the integration of logistics activities so as to improve the environment.

b) Green Production: Production processes may influence GSCM in many forms, such as the ability to use certain materials (recycle/reusable/remanufactured); the capacity to integrate remanufactured or reusable components in the system; the design of processes to prevent waste; the capacity of process improvement and innovation in the pursuit of sustainability; and the ability to introduce new environmentally friendly technologies and new production processes. Thus, this performance index intends to measure the level of the Production activities integration in GSCM.

c) Reverse Logistics: As mentioned above, Reverse Logistics is an important part in GSCM. So, this set of indexes measures the level of material and energy reduction, recycling materials, remanufacturing, reuse and waste disposal, according to GSCM principles.

d) Green Procurement/Acquisition: The objective is to measure the level of procurement and management of both recyclable or reusable materials and the cooperation and integration with the suppliers for environmental purposes.

e) Green Warehousing: The intention is to measure the security in the storage of various products in order to prevent pollution and risks to the environment; space optimization for products storage; and energy consumption reduction.

f) Green Packing: Packaging has a strong relationship with other components of operational life cycle. Package characteristics such as size, shape and materials have an impact on the distribution because they affect the transport characteristics of the goods, as well as the costs of materials and the
fuel/energy consumption. Thus, this set of indexes aims to measure the level of the use of environmentally friendly material and technologies in packing.

g) **Green Transport and Distribution:** Distribution and transportation network operations are important characteristics that may influence the GSCM in the location of points of distribution and sales; transportation modes; control systems; and just-in-time policies. This set of performance indexes aims to measure the transport and distribution strategies in both direct logistics and in the GSCM activities.

h) **Green Marketing:** The objective is to measure the impact of the companies’ green strategies and their relations with consumers and the general public, as well the cooperation among suppliers, consumers and companies for cleaner and greener logistics operations.

i) **Eco-Design:** The purpose is to measure the level of product design integration to GSCM activities. This means to evaluate the product design integration in the network in order to reduce material and energy consumption as well as promote quality.

3. METHODOLOGY

The research presented here is part of a larger study that focuses on the development of performance indexes for the GSCM specific to the oil and gas industry, as mentioned above. In order to study and evaluate the indexes, a study was carried out on companies from the oil and gas industry business chain located in Campos Basin, in Macaé, state of Rio de Janeiro, in Brazil. The indexes proposed to the oil and gas industry GSCM were transformed into a structured questionnaire that has been applied to companies from the mentioned industry. The analysis of the results of this exploratory study will be discussed in the following sections.

The questionnaire was divided in two parts. The first had questions related to the general information about the companies, such as size, number of employees, turnover and sales. The second was about the importance of the theoretical performance indexes related to GSCM to oil and gas industry. It was asked that the interviewees of the companies give an importance grade to each one of the following performance indexes presented: grade 1 was awarded to the least important and grade 5 to the most important factor for business, grade 0 having been applied to non-applicable cases and also for not answering the question.

Managers from the companies listed by REDE PETRO-BC (a Business Association for oil, gas and energy companies located in Campos Basin) were invited to participate in the study by personal telephone calls. The final sample consisted of those companies whose managers agreed to the interviews for this first part of the study. Five managers from five different companies agreed to participate, at this stage. The companies’ names were kept anonymous due to the ethical research reasons.

4. RESULTS AND DISCUSSIONS

Some characteristics of the companies that participated in the exploratory study can be seen on Table 1. The companies are from the oil and gas industry business chain and are integrated in the oil and gas industry as suppliers of products and services such as pipelines, tubes, surface treatment products, maintenance and industrial services to oil and gas exploiters and producers. The companies’ respondents were logistics managers or production managers; 04 companies classified themselves as medium sized companies and only 01 company was of large size. Relative to the employee numbers, all the companies’ respondents answered that they have both employees and outsourced personnel. One interviewee declared that the company where he worked had between 10 and 49 employees, and less than 10 outsourced personnel. Three other companies had between 100 and 200 employees and less than 10 outsourced personnel. The largest company had more than 1000 employees and outsourced personnel.

All the companies are multinational enterprises. Two companies have their headquarters located in France, one in the USA, and the others in Brazil. The number of employees in the companies is the number of personnel working in the operations in Campos Basin, in Brazil. Concerning the turnover, 01 company declared that it amounted to more than US$ 25 million (large company), 03 companies from US$ 10 million to US$ 15 million, and 01 from US$ 2.5 million to US$ 5 million. Next we will present the results of the answers to the second part of the questionnaire about the importance of the theoretical performance indexes related to GSCM to oil and gas industry.
### Table 1 – General information about the companies

<table>
<thead>
<tr>
<th>Company size</th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
<th>Company E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of employees</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
<td>large</td>
</tr>
<tr>
<td>Number of outsourced employees</td>
<td>from 11 to 50</td>
<td>from 100 to 200</td>
<td>from 100 to 200</td>
<td>from 100 to 200</td>
<td>more than 1000</td>
</tr>
<tr>
<td>Number of outsourced employees</td>
<td>up to 10</td>
<td>up to 10</td>
<td>up to 10</td>
<td>up to 10</td>
<td>more than 1000</td>
</tr>
<tr>
<td>Annual average turnover (million US$)</td>
<td>from 2.5 to 5.0 million</td>
<td>from 10.0 to 15.0 million</td>
<td>from 10.0 to 15.0 million</td>
<td>from 10.0 to 15.0 million</td>
<td>more than 25.0 million</td>
</tr>
<tr>
<td>Market</td>
<td>Multinational company Headquarter located in USA</td>
<td>Multinational company Headquarter located in Brazil</td>
<td>Multinational company Headquarter located in France</td>
<td>Multinational company Headquarter located in Brazil</td>
<td>Multinational company Headquarter located in France</td>
</tr>
<tr>
<td>Business</td>
<td>Services to oil and gas production companies as oil drilling stimulation and CO₂ pumping.</td>
<td>Services to oil and gas production companies providing surface treatment products and maintenance.</td>
<td>Services to oil and gas production companies providing industrial services in thermal treatment, industrial coatings and thermochemical.</td>
<td>Services to oil and gas production companies providing specialty steel.</td>
<td>Services to oil and gas production companies providing seamless and special steel tubes and pipes.</td>
</tr>
</tbody>
</table>

### 4.1 Managing Internal Environment

All the interviewees confirmed the existence of environmental management systems as well as ISO 14000 certification. They also sustained reducing pollutants emissions (air, waste, solid disposal etc.) and consumption of hazardous/toxic/pollutant materials. The commitment of senior managers as well managers to support GSCM was considered very important factors for the GSCM success in oil and gas industry.

The interviewee from the Company B that works with surface treatment products, considered the environment total quality management factor as the least important. The interviewee of the Company C, which also works with chemical products, answered that the integration of logistics flow to improve the environment is not important. The other factors were considered of medium importance.

### 4.2 Reverse Logistics

The interviewee from Company B graded zero to all the indexes related to Reverse Logistics, except to the percentage of incinerated or discarded products and eco-efficiency, which were considered as a very important factor. The interviewee from the Company D graded all the indexes as very important or important, except for the rate of products and materials return. The number and location of facilities for collection/recovery of materials and/or products was graded as very important by all the respondents, excepted for the interviewee from Company B, as mentioned above. The other factors were considered of medium importance.

### 4.3 Green Production

According to most of the respondents the total consumed energy and material (water, fluids, perforating, steel etc.) were graded as very important for green production activities, except for the interviewee from Company B, who considered most of all the indexes as not important or least important.
The percentage of recyclable/reusable materials (volume or weight) used in production were considered an important factor to the companies, except for the interviewee mentioned above. The other factors were considered of medium importance.

4.4 Green Purchasing/Acquisition
All the interviewees from the companies graded the cooperation with suppliers for environmental objectives and ISO 14000 certification for suppliers as very important factors for green purchasing/acquisition activities in GSCM. The other factors were not considered important for all the companies.

4.5 Green Warehousing
Inventory control policies for both raw materials and for recycled, remanufactured and reusable material and safety in storage of various products were considered as very important factors for all the respondents, in relation to the green warehousing indexes. The reduction of inventory levels for both raw materials and for recycled, remanufactured and reusable materials and energy consumption in storages were graded of the least importance for the interviewee from Company D. The other factors were considered of medium importance for the other respondents.

4.6 Green Packaging
The use of environmentally friendly materials in package design was graded as the least important factor for the respondents related to green packaging indexes, except for the interviewee of the largest company (company E), who considered it as an important factor. However, the interviewee from Company E answered that the use of clean technologies in packing was not important, as opposed to the other interviewees who considered this factor as very important. The use of environmentally friendly material in packing was graded as important for all the respondents. The other factors were considered of medium importance.

4.7 Green Transport and Distribution
Most of the interviewees graded the optimization of the distribution process through better routing and delivery scheduling; the use of integrated delivery (consolidated) to reduce transport; the use of environmentally friendly technology in transport; and the management of the direct and reverse flow of materials to reduce transportation as important factors to the green transport and the distribution activities. The interviewee from Company C considered the mentioned factors as not important. The other factors were considered of medium importance for the other respondents.

4.8 Eco-Design
The Eco-Design indexes, such as: product design in order to reduce material consumption/energy; product design aimed at reusing and recycling materials and components; product design to avoid or reduce the use of hazardous products and/or their manufacturing processes; and eco-design to promote quality were graded as very important only for the interviewees from Companies B and E. The remainder of the respondents considered the mentioned indexes as not important.

4.9 Green Marketing
The interviewee from Company C considered all the green marketing indexes as not important to GSCM. On the other hand, the rest of the respondents graded the following process as very important: the accreditation and the criteria for selection of suppliers to the final consumers; collecting procedures and incentive systems to customers for reverse logistics operations; and the cooperation with customers for a cleaner production and green packaging. The cooperation with customers for eco-design was considered as less important for the other respondents.

4.10 Discussion
The interviewees of the companies which participated in this exploratory study perceived as very important the commitment of the managers in promoting the GSCM for the companies inserted in the oil and gas industry chain. Also, they stressed the relevance of the management systems focused on environmentally
sustainable activities and processes. According to [9, 10, 12, 17], this is an important point for GSCM practices implementation. On the other hand, the importance of logistics flow and integration was not seen as an important factor for one interviewee. That fact may show that even with the awareness of the relevance of an integrated management and their commitment to promote GSCM, the role of the logistics’ activities integration for the existence of a complete GSCM does not seem to be perceived as important for all of them. This corroborates [9] as many companies have failed to manage GSCM due to the difficulties not only in developing performance indexes but also in understanding the role of the complete integration among all the supply chain’s activities.

It is interesting to notice that most of the respondents have perceive ISO 14000 certification as important for the companies as well as for the suppliers. Also, the respondents considered as important factors others activities listed in the questionnaire. This indicates that the companies have been increasing their awareness of the role of the impacts of the processes and activities on the environment, as mentioned by [7, 12]. Also, all the companies presented in this study are multinational enterprises and have not only partners in Brazil but worldwide and outsourced personnel. As showed by [19], the sensibility to multicultural issues helps the understanding of many crucial factors concerning business and logistics partnership around the world, as the companies are inserted in a global business chain.

It is also important to highlight that the respondents answered the questions according to their understanding of their business processes, products and services. As has been shown above, there were some companies that answered questions differently from the majority, such as the interviewee from Company B, who graded zero to the reverse logistics indexes but who, on the other hand, considered the commitment of the managers and ISO 14000 certification for the company and suppliers as very important. This may show that there might be a hiatus between the perception of the respondent to GSCM activities and indexes and the reality of the company operations. The same thing occurred in relation to the other respondents, as well. For instance, in relation to managing internal environment, reverse logistics, green production, warehousing, packing, transport and distribution most of the respondents answered that many of these indexes were of medium importance. However, they were aware that other indexes or activities were important. This confirms some statements made by [7, 9, 10, 12, 18], that GSCM awareness has increased in the recent years, but there still lies a long way to improve the processes and the integration of the whole chain in a greener perspective.

5. CONCLUSIONS

The primary aim of this investigation was to illustrate the application of a set of theoretical indexes proposed to the oil and gas industry Green Supply Chain Management through a study conducted in companies located in Campos Basin, in Brazil. Most of the Brazilian oil and gas production is offshore and there is a concern related to the environmental damages of the mentioned industry, not only in the Brazilian coast but worldwide.

Green Supply Chain Management can be seen as an ally to the oil and gas industry business activities as it shows more environmental awareness by implementing environmentally friendly activities and processes along the whole chain. Appropriate indexes capable to measure the performance of industries’ Green Supply Chain Management were presented in this research.

The set of presented indexes is the beginning of a deeper study focusing on monitoring Green Supply Chain Management and green logistics activities in the oil and gas sector. In general, the measurement system through the presented indexes can provide organizations with a comprehensive overview of their activities and operations, aiming at sustainability and to less damage to the environment. Therefore, such on perspective should boost the improvement of their image and competitiveness, especially in Brazil, with the discovery of new reserves and the beginning of the pre-salt exploration.

We would like to stress that the performance indexes presented in this paper can certainly be improved and complemented with other indicators. However, we believe that those indexes may be useful for evaluating the performance of Green Supply Chain Management for companies in the oil and gas sector, as well as for helping them to consider their processes and operations within a "green" perspective.

We recommend that future studies investigate the application of the indexes in a large range of oil and gas companies, not only in Brazil, but in other countries as well, in order to expand the present indexes. We also suggest investigations on partnerships and their role to improve GSCM strategies should be carried out. In
this sense, it is important to check the relation and the integration among the supply chain partners, and third partners, as well as multicultural aspects involved in those processes as the companies make business with other ones located in different parts of the globe.

6. REFERENCES


INFLUENCE OF STOCK SHORTAGE IN INTEGRATED LOGISTIC SYSTEMS: AN UNDER-ESTIMATED IMPORTANCE

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Abstract

When evaluating performance of flow systems with such indicators as "throughput" or "response time", it is known that random delays with high dispersions degrade significantly the performances of the systems. Here we focus on the particular case of stock shortages in integrated logistic systems. Because these stock shortages create random delays on the component delivery, they are the sources of disorders in the behaviors of the systems they impact. In this paper, we study the squared coefficient of variation of the random variable which is a pertinent metric for evaluating the risk on the performances of the flow systems involved by the dispersion of the variable. After elaborating a realistic random model of an inventory, we present a way to exhibit the squared coefficient of variation of the duration of the stock shortages. In the following part, we consider the random variable corresponding to the potential waiting times of all the orders which, for well tuned systems, has a relatively high probability to take the value zero. We show that the distribution of this latter variable admits a squared coefficient of variation much higher that the former one. We also exhibit a few numerical examples in order to raise the reader awareness of the risk of under-estimating the importance of the stock shortage in integrated logistic systems.

Keywords: integrated logistic system, stock shortage, backorder, performance of flow systems, coefficient of variation.

1 INTRODUCTION

When evaluating performance of flow systems with such indicators as "throughput" or "response time", it is known that random delays with high dispersions degrade significantly the performances of the systems.

Here we focus on the particular case of stock shortages in integrated logistic systems. Because these stock shortages create random delays on the component delivery, they are the sources of disorders in the behaviors of the systems they impact. Generally, when these systems are audited, only the average delay of the random phenomena is considered and received as a constant time. Sometime this average delay is even canceled if the value is considered as low with respect with the other execution times exhibited in the flow chart or the system under investigation. However, several inventory models with backorders have been developed in the past, from different perspectives. Basically, two factors can be penalized, the probability of facing a backorder for a demand and the expected duration of the backorder (fixed and linear backorder costs). And researchers have put a lot of efforts in exhibiting their optimal solutions ([5], [7], [8]).

Here, our objective is to give to the engineer or to the auditing team more information on the potential risk of such random phenomena. For that we focus our study on the squared coefficient of variation of the random variable which is a pertinent metric for evaluating the risk on the performances of the flow systems involved by the dispersion of the variable. A random delay with a coefficient of variation taking the value one is already a significant source of perturbation for the system. When elaborating stochastic models, the square of the coefficient of variation is generally used, just because the formal expression of the square is more expressive (for example, the squared coefficient of variation of an Erlang-k distribution is just \(1/k\)).

In this paper, we first elaborate a realistic random model of an inventory. We consider the situation where a truck fleet of \(m\) units is maintained within the company and some spares have been supplied in the workshop in
order to increase the efficiency of the maintenance. We focus on the spares of a specific type. Among several possibilities, we assume that each consumption enables a new order such that the resource level is maintained constant.

We then present a way to exhibit the squared coefficient of variation of the duration of the stock shortages (Section 2). Then we determine in Section 3 the distribution of the potential waiting times of all the orders and the associated squared coefficient of variation. We show that these squared coefficients of variation are particularly high when the stock shortages are not so frequent. Finally, as a conclusion, we summarize the main presented results.

2 DETERMINATION OF THE SQUARED COEFFICIENT OF VARIATION OF THE STOCK SHORTAGES

In order to study the influence of stock shortages, we first need to elaborate an inventory model. Based on the studied case (the maintenance of a truck fleet), we propose to consider an inventory with a maximum level \( R \) and unitary re-order where, if \( m \) is the total number of trucks of the fleet, the conditional demand rate \( \lambda(i) \) can be written as:

\[
\lambda(i) = \inf(m, m + i)k\lambda_e \quad i = R, R - 1, ..., 0, -1, ..., -m ,
\]  

where \( i \) denotes the net level of the stock (number of spares on the shelf minus the number of eventual back-orders).

To keep things simple, we assume that the random delivery delays are independent and identically distributed according to exponential random variables with rate \( \mu \). With these assumptions, the inventory can be modeled by a Birth-Death Markovian process where the \( \lambda(i) \) are the birth rates while the rates \( \mu(i) \), such that:

\[
\mu(i) = (R - i)\mu \quad i = R - 1, ..., 0, -1, ..., -m ,
\]  

can be considered as the death rates. A representation of this Birth-Death Markovian process is given on Figure 1.

![Figure 1: Inventory model. Independent delivery delays.](image)

When considering Figure 1, a stock shortage always starts when the Markovian process makes a transition from state 0 to state \(-1\) and stops when the process makes a transition from state \(-1\) to state 0. To study the sojourn times of the stock shortages, it is convenient to rename the corresponding states as they are designed on Figure 2. Here, a sojourn time starts in state 1 and finishes when reaching the absorbing state \( a \). This new process with \( (m + 1) \) states is sufficient to determine the distribution of the sojourn times. Let \( S \) denote the subset of the \( m \) transient states \( 1, 2, ..., m \).

![Figure 2: Sojourn time of the stock shortages.](image)
If we order these states as 1, 2, ..., \( m \) and \( \alpha \), we obtain the following infinitesimal generator matrix of the new process:

\[
A = \begin{bmatrix}
-((R + 1)\mu + (m - 1)\lambda) & \cdots & 0 & 0 & 0 \\
(R + 2)\mu & -((R + 2)\mu + (m - 2)\lambda) & \cdots & 0 & 0 \\
0 & (m - 1)\lambda & \cdots & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots \\
R \lambda & \alpha & \cdots & 0 & 0 \\
0 & 0 & \cdots & (R + m)\mu & -((R + m)\mu + (m - 3)\lambda)
\end{bmatrix}
\]  

(3)

The \( m \) first states correspond to the subset \( S \) of the possible states of a sojourn time. Since they are transient, we can extract from matrix \( A \) the sub-matrix \( A_S \):

\[
A_S = \begin{bmatrix}
-((R + 1)\mu + (m - 1)\lambda) & \cdots & 0 & 0 \\
(R + 2)\mu & -((R + 2)\mu + (m - 2)\lambda) & \cdots & 0 \\
0 & (m - 1)\lambda & \cdots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
R \lambda & \alpha & \cdots & 0 \\
0 & 0 & \cdots & (R + m)\mu
\end{bmatrix}
\]  

(4)

and use the established result (cf. [9]) giving the distribution of the sojourn times \( T_S \) in subset \( S \):

\[
P(T_S \leq t) = 1 - \alpha e^{A_S t} e
\]

where \( e \) is the unity column vector (whose transpose is the line vector \((1, 1, 1, \ldots, 1)\)) and \( \alpha \) is the line vector of the initial probabilities \((1, 0, 0, \ldots, 0)\), since the sojourn period in the back-order states starts in state 1 with probability one.

From that result, it is possible to determine the expectation of \( T_S \):

\[
E[T_S] = \int_0^\infty (1 - P(T_S \leq t)) dt = \int_0^\infty \alpha e^{A_S t} e dt = \alpha \left[ A_S^{-1} e^{A_S t} \right]_0^\infty e = -\alpha A_S^{-1} e
\]

(5)

and its second moment:

\[
E[T_S^2] = (-1)^2 \frac{d^2}{ds^2} L_{T_S}(0) = 2 \alpha A_S^{-2} e
\]

(6)

where \( L_{T_S}(0) \) denotes the Laplace transform \( L_{T_S}(\phi) \) of the probability distribution of \( T_S \), when \( \phi = 0 \).

Note that we don’t need to compute the inverse of matrix \( A_S \) to get the values we are interested in. If we define the line vector \( x \) as equal to \(-\alpha A_S^{-1} \), we can determine the vector \( x \) by solving the linear system:

\[
x A_S = -\alpha
\]

(7)

and then get \( E[T_S] \) as \( E[T_S] = xe \).

Then, defining the line vector \( y \) as equal to \( 2\alpha A_S^{-2} \), we can write \( y A_S = 2\alpha A_S^{-1} = -2x \). Therefore, we can determine the vector \( y \) by solving the linear system:

\[
y A_S = -2x
\]

(8)

and finally we get \( E[T_S^2] \) as \( E[T_S^2] = ye \).

As a little example, let us determine the expressions of these two moments when \( m = 3 \) and \( R = 1 \). The system \( x A_S = -\alpha \) here corresponds to:
\[-2(\mu + \lambda)x_1 + 3\mu x_2 = -1\]
\[2\lambda x_1 - (3\mu + \lambda)x_2 + 4\mu x_3 = 0\]
\[\lambda x_2 - 4\mu x_3 = 0\]

and gives the solution:
\[x_1 = \frac{1}{2\mu}, \quad x_2 = \frac{\rho}{3\mu}, \quad x_3 = \frac{\rho^2}{12\mu},\]
where $\rho$ denotes the ratio $\lambda/\mu$.

We are also able to solve the system $y A_S = -2x$:
\[-2(\mu + \lambda)y_1 + 3\mu y_2 = -2x_1\]
\[2\lambda y_1 - (3\mu + \lambda)y_2 + 4\mu y_3 = -2x_2\]
\[\lambda y_2 - 4\mu y_3 = -2x_3\]

As a function of the $x_i$'s, the solution is:
\[y_1 = \frac{1}{\mu}(x_1 + x_2 + x_3); \quad y_2 = \frac{2}{3\mu}(\rho(x_1 + x_2 + x_3) + x_2 + x_3) ; \quad y_3 = \frac{2\rho}{12\mu}(\rho(x_1 + x_2 + x_3) + x_2 + x_3) + \frac{1}{2\mu}x_3.\]

So we get
\[E[T_S] = x_1 + x_2 + x_3 = \frac{1}{2\mu} + \frac{\rho}{3\mu} + \frac{\rho^2}{12\mu} = \frac{1}{\mu}\left(\frac{6 + 4\rho + \rho^2}{12}\right),\]
and
\[E[T_S^2] = y_1 + y_2 + y_3 = 2(x_1 + x_2 + x_3)\left(\frac{1}{2\mu} + \frac{\rho}{3\mu} + \frac{\rho^2}{12\mu}\right) + x_2\left(\frac{2}{3\mu} + \frac{\rho}{6\mu}\right) + x_3\left(\frac{7}{6\mu} + \frac{\rho}{6\mu}\right) = 2(x_1 + x_2 + x_3)^2 + \frac{x_2}{\mu}\left(\frac{4 + \rho}{6}\right) + \frac{x_3}{\mu}\left(\frac{7 + \rho}{6}\right).\]

Now, we can express the squared coefficient of variation of the duration of the stock shortages:
\[CV^2_{T_S} = \frac{E[T_S^2]}{(E[T_S])^2} - 1\]
\[= 2 + \left[\frac{x_2}{6\mu}(4 + \rho) + \frac{x_3}{6\mu}(7 + \rho)\right]\left(\frac{12\mu^2}{(6 + 4\rho + \rho^2)^2}\right) - 1\]
\[= 2 + \frac{\rho}{18\mu^2}\left[(4 + \rho) + \frac{\rho}{4}(7 + \rho)\right]\left(\frac{12\mu^2}{(6 + 4\rho + \rho^2)^2}\right)
= 1 + 2\rho\left(16 + 11\rho + \rho^2\right)\left(\frac{12\mu^2}{(6 + 4\rho + \rho^2)^2}\right).\]
From its expression, we see that the squared coefficient of variation of $T_S$ is never lower than one and tends to one when $\rho$ tends to zero or to infinity. Figure 3 represents $CV^2_{T_S}$ as a function of $\rho$. The maximal value of the curve is around 1.52 and this maximum is obtained for $\rho \approx 1.86$. Note that in the real situation, it is expected to have low values of $\rho$, this means that $CV^2_{T_S}$ will be close to one.

![Figure 3: Representation of $CV^2_{T_S}$ as a function of $\rho$, with $m = 3$ and $R = 1$.](image)

If we look at a larger numerical example, we have to use a numerical software to solve the linear systems. Let us consider the numerical example of an inventory of a spare dedicated to a fleet of $m$ trucks. Here, $m = 20$, $R = 1$ and we want to observe the evolution of the squared coefficient of variation of the duration of the stock shortages as the ratio $\rho = \lambda / \mu$ is increased. Note that we don’t need to specify the individual values of parameters $\mu$ and $\lambda$ since the squared coefficient of variation is time scale independent. For each value of $\rho$, we need to solve the two linear systems (7) and (8). So we use a LU decomposition (cf. [3]) of matrix $A_S$ in order to write:

$$xLU = -\alpha,$$

(9)

and first solve $zU = -\alpha$ and then, knowing the vector $z$, solve $xL = z$ in order to get the vector of interest $x$.

Then, using the computed matrices $L$ and $U$, we follow the same methodology to get vector $y$.

On Figure 4, we represent the values of $CV^2_{T_S}$ as a function of $\rho$ (for $m = 20$ and $R = 1$). The maximal value of the curve is around 2.06 and this maximal is obtained for $\rho \approx 0.23$.

Re-observing Figure 2 above, we can understand that, when $\rho$ tends to zero, the sojourn time distribution will tend toward an exponential distribution of rate $(R + 1)\mu$, distribution that admits a $CV^2_{T_S}$ equal to one. And since again, in the real situation, it is expected to have low values of $\rho$, the corresponding value of the $CV^2_{T_S}$ will not be far from value one.
3 DETERMINATION OF THE SQUARED COEFFICIENT OF VARIATION OF THE WAITING TIMES

We model the waiting time for spares as a phase-type distribution with states numbered from 0 to \( m \). The state \( i \) corresponds to the situation where the request for the spare is ranked in position \( (m - i) \) in the FIFO waiting list (cf. Figure 5). On this figure, \( \pi_i \) denotes the probability that the phase-type distribution of a given request starts in state \( i \) (determination of values \( \pi_i \) is exposed below in the appendix).

Setting \( n = m + R \), the delivery rate is equal to \( (n - i)\mu \) when the phase-type distribution is in state \( i \), \( i = 0, 1, ..., m - 1 \).

Let \( p_i(t) \) denotes the probability that the phase-type distribution is in state \( i \), \( i = 0, 1, ..., m - 1 \). We have shown in [6] that this probability \( p_i(t) \) can be written with the following form, for all \( i = 0, 1, ..., (m - 1) \),

\[
p_i(t) = \sum_{k=0}^{i} \pi_k \left( \begin{array}{c} n - k \cr i - k \end{array} \right) (e^{-\mu t})^{n-i} (1 - e^{-\mu t})^{i-k}
\]

The probability that the waiting time \( W \) takes a value greater than \( t \) is given by :

\[
P(W > t) = \sum_{i=0}^{m-1} p_i(t)
\]

Note also that the random variable \( W \) has a positive probability to be null :

\[
P(W = 0) = 1 - \sum_{i=0}^{m-1} \pi_i .
\]
Given this distribution, we show in [10] that the first and second moments of the waiting time $W$ can be written as:

\[
\mathbb{E}[W] = \sum_{j=0}^{m-1} \frac{A_j}{\gamma_j}
\]

\[
\mathbb{E}[W^2] = \sum_{j=0}^{m-1} \frac{2A_j}{\gamma_j^2}
\]

where $\gamma_i = (n - i)\mu$ and

\[
A_j = (-1)^{m-j-1} \binom{n-j-1}{m-j-1} \sum_{k=0}^{j} \pi_k \binom{n-k}{j-k} .
\]

This allows us to compute the squared coefficient of variation of $W$:

\[
CV^2_W = \frac{\mathbb{E}[W^2]}{\mathbb{E}[W]^2} - 1.
\]

Considering again the numerical example of Section 2 ($m = 20$ and $R = 1$), we compute the squared coefficient of variation $CV^2_W$ of the waiting time for a missing spare. The results are presented on Figure 6. We realize that this new squared coefficient of variation is much higher than the one we obtained for the shortage times when the value of parameter $\rho$ is small. With Figure 7, we zoom on the interval $\rho \in [0.005, 0.015]$ and we can observe that the squared coefficient of variation is greater than 6 if $\rho \leq 0.015$. We do not look at larger values of $\rho$ greater than 0.015 because, for $\rho = 0.015$ the rate of backorders equals already 26%. But if we were increasing the backorder rate up to non realistic high values (close to 100%), the squared coefficient of variation could take a value lower than 1.

![Figure 6: Representation of $CV^2_W$ as a function of $\rho$, with $m = 20$ and $R = 1$.](image)
Figure 7: Zoom on the representation of $CV^2_W$ as a function of $\rho$, with $m = 20$ and $R = 1$.

The main difference between the two squared coefficients of variation $CV^2_{T_S}$ and $CV^2_W$ is that the latter is significantly higher than the one of the former if $\rho$ is low. But, for a large fleet, we have to be in the situation of a small $\rho$ in order to obtain a good availability of the truck fleet. This means that if the existences of backorders will be relatively rare events, because of high squared coefficient of variation, the effect will be consequent on the behavior of the logistic organization.

We remark that, when $\rho$ tends to zero, $CV^2_W$ tends to infinity while $CV^2_{T_S}$ tends to one. This is due to the fact that the probability $P(W > 0)$ tends to zero when $\rho$ tends to zero. Denoting $Z$ the random variable defined as follows:

$$P(Z > t) = P(W > t | W > 0),$$

we can remark that this random variable $Z$ can be seen as the waiting times of the back-orders. From this definition, we deduce that:

$$\mathbb{E}[Z] = \mathbb{E}[W | W > 0] = \frac{\mathbb{E}[W]}{P(W > 0)},$$

$$\mathbb{E}[Z^2] = \frac{\mathbb{E}[W^2]}{P(W > 0)},$$

and

$$(CV_Z^2 + 1) = P(W > 0)(CV_W^2 + 1).$$

So the squared coefficient of variation $CV_Z^2$ which reflects the variation of the positive waiting time (with this random variable $Z$ we ignore the fact that most of spare requests are immediately satisfied) will be significantly smaller than $CV_W^2$. In fact, we expect that the distribution of the random variable $Z$ will tend to the exponential one when $\rho$ tends to zero and that $CV_Z^2$ will tend to one.

Keeping the same example, we get for $\rho = 0.006$: $P(W > 0) = 0.1128$, $CV^2_W = 16.5114$ and $CV_Z^2 = 0.9746$. While for $\rho = 0.003$, we get: $P(W > 0) = 0.0582$, $CV^2_W = 33.1752$ and $CV_Z^2 = 0.9863$. As we could expect, we observe that the probability $P(W > 0)$ is decreasing when $\rho$ decreases. Since the distribution of the
random variable $Z$ is a phase-type distribution of the family of a series of phases, it is not surprising that $CV_Z^2$ is lower than one and increasing when $\rho$ tends to zero.

Finally, we can say, when the stock shortage is relatively a rare event, that the effect on flow systems is important ($CV_Z^2$ is very high) and, despite a low average value of the waiting time, the delay is no more negligible when it occurs.

4 CONCLUSION

With this study, we addressed the potential risk of stock shortages in integrated logistic systems. After elaborating a realistic random model of an inventory, we presented a way to exhibit the squared coefficients of variation of the duration of the stock shortages and of the waiting times respectively. If the squared coefficient of variation of the duration of the stock shortages generally takes its value around one or two, the squared coefficient of variation of the duration of the waiting times can takes its value above ten. Such a value corresponds to a rare but consequent event which can be cause of severe perturbations. More over increasing the availability of the system (by increasing parameter $R$, for example) on the one hand decreases the probability of back-order occurrences, but, on the other hand, increases the squared coefficient of variation $CV_W^2$ of the duration of the waiting times. In particular in such a situation, this means that, despite a low average value of the waiting time, the non null delay is no more negligible when it occurs.

References


Appendix : Computation of the input probabilities $\pi_i$, $i = 0, \ldots, (m - 1)$

We first have to determine the steady state probabilities $(q_R, q_{R-1}, \ldots, q_0, \ldots q_{-m})$ of the inventory model. Starting from the definitions of $\lambda(i)$ and $\mu(i)$ (cf. relations 1 and 2), we get these probabilities by using the balance equations $\mu(i)q_i = \lambda(i+1)q_{i+1}$ and the normalizing equation

$$\sum_i q_i = 1.$$

Then, knowing these steady state probabilities $(q_R, q_{R-1}, \ldots, q_0, \ldots q_{-m})$, we compute the global flow $\Phi$ of spare requests that is equal to :

$$\Phi = \sum_{j=-m}^{R} \lambda(j)q_j.$$
If $R$ is strictly positive, the flow of requests that are served without delay is equal to:

$$\sum_{j=1}^{R} \lambda(j)q_j,$$

while the flow of the requests which append when the inventory net level is in a non positive state $j$ can be written as:

$$\lambda(j)q_j \quad j = 0, -1, ..., -(m - 1).$$

Now, a request which appends while the inventory net level is in the non positive state $j$ will have to suffer of a waiting time starting in state $i$ of the phase type distribution where $i = j + m - 1, i = 0, -1, ..., -(m - 1)$ (cf. Figure 5). The probability of that occurrence corresponds to:

$$\pi_i = \frac{\lambda(j)q_j}{\Phi} \quad \text{with} \quad j = i - (m - 1).$$

Let us remark that, if $R$ is positive, then the sum of the $\pi_i$ probabilities is lower than one and we have:

$$\sum_{i=0}^{(m-1)} \pi_i = 1 - \frac{\sum_{j=1}^{R} \lambda(j)q_j}{\Phi}.$$
AUTOMATED INTERNET-SHOPPING TERMINALS FOR SELF-SERVICE PICK-UPS

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Abstract

In near future effective design and user friendliness of easy to use pick-up stations will be an essential success factor for internet shopping. To reduce delivery traffic and to allow safe handover possibilities for parcel services comfortable pickup terminals become a necessary element of supply chains.

An Austrian research consortium developed an innovative depot system for passenger’s luggage at railway stations and at public hot spots like shopping centers. This system represents a new cube adaptive storage technology for luggage and bags and incorporates a novel concept for effective warehousing and handling of parcels, too. The paper provides an overview about needs and expectations and describes the web-based functionalities and benefits for operators and users.

Keywords: Storage Equipment and Systems, Intralogistics, Logistics Technology, Automation in Logistics, Web-based Logistics

1. INTRODUCTION

The rapid rise of web-based deliveries constantly increases the volumes and the amount of last mile transports. Market needs for short time delivery cycles and requested service levels lead to high shipping cycles and low utilization rates for used vehicles. On the contrary for private customers it is often not attractive to wait for announced deliveries, which leads to unnecessary multiple delivery attempts.

Therefore parcel service industries try to offer more and more pick-up station in the self-service zones of post offices or at petrol stations as an alternative depository for internet shipments. If the consignee is at the time of delivery not at home, he obtains as usual a note - the "yellow note". At self-service pick-up stations it is possible to pick-up deliveries around the clock. For this purpose, the notification slip is printed with a simple bar code to be identified by a reader at the pick-up station. A correct read (and sometime an extra requested pin code) automatically opens an appropriate tray, where the shipment was stored before.

Also for the public transport sector it is an essential success factor to increase attractiveness not only by high performance of traffic systems. Railway stations face increasing demands for more comfortable temporary deposits of luggage or shopping bags, too. Conventional luggage lockers are inefficient concerning utilization of limited space and create problems in their use for old or handicapped passengers. New integrated concepts for modern railway stations shall provide multifunctional benefits for travelers, local service providers and internet retailers.

In order to support more sustainable and active forms of mobility, it is necessary to develop ground-breaking logistic systems not only for the travelers themselves, either regarding their daily routine or journeys, but also for their luggage and for their internet shopping deliveries, too. The idea is, to combine the growing needs of travelers or commuters with the possibility to utilize their waiting times for the parcel pick up of their internet deliveries.
To address such changing mobility demands and internet buying habits of future travelers a research study funded by the Austrian “FFG” (Austrian Research Promotion Agency) investigated the requirements and demands for temporary storing possibilities of luggage and for deliveries at railway stations. The study [1] was based on a broad investigation of essential traveler requirements and expectations for future luggage storage and drop up systems. Modern public storage and pickup services should be available in short-term to avoid troublesome handling of luggage and significant stress factors for all passengers.

At future railway stations or similar hot spots of public transportation the release from luggage and an easy to use pick-up during waiting times should be an important factor to increase the attractiveness and efficiency of public transportation systems in general. Beside short travel connections and centrally located railway stations public transport also requires just comfortable depot systems.

The finally designed depot service concept (named Store&Go+) represents such an innovative system for short term and long term storage of traveler’s luggage at railway stations, but is also foreseen to be used as pick-up place for internet shopping or theoretically can be used as parcel buffer at distribution hubs in the logistic industry, too.

After initial investigations and fact findings the Austrian research consortium developed a new and as experimental prototype for passenger’s luggage or baggage. This Store&Go+ system includes a new cube adaptive technology for containers which can be top loaded at extremely user friendly drop stations. The system incorporates a novel concept for effective warehousing and handling of luggage, too.

The construction details provide integrated answer to the needs and expectations of all kind of potential users and address the needs and operational conditions of station operators, too. In order to integrate demands from different perspectives the Store&Go+ prototype was developed during a two-year inter-university research collaboration of the universities of applied sciences in Steyr, Wels and St.Pölten in alliance with the Viennese research company netwiss. The Austrian Federal Railways “ÖBB” and the leading Austrian logistics systems integrator “TGW” joined the research team as practical think tanks, too and the development was funded by the Austrian Research Promotion Agency “FFG”.

2. THE NEW PERSPECTIVE FOR RAILWAY STATION OPERATORS

The developed Store&Go+ concept provides an easy way of luggage deposit and overcomes the disadvantages of conventional locker systems (e.g. the difficulty of handling of heavy luggage, which is deemed acceptable to older or weaker travelers). Instead of side or front loaded lockers the Store&Go+ system uses specialised 3-sided containers which can be filled from the top and from the front side at automated loading stations in ergonomic working height.

![Figure 1. Parcel pickup station by the Austrian Post](image-url)
Figure 2. Disadvantages of conventional locker systems compared with an
ergomonic and easy to handle drop station

To protect the personal belongings of the user each container is covered and sealed automatically before its transfer into an automated storage area.

Fully automated and industrially standardised storage and retrieval systems (“Commissioner”) - which are already well established and approved in many installations store the closed and locked container into a background racking system. In parallel the user gets a barcoded ticket to pick up his luggage again whenever he likes.

For the railway station (or airport) operators – who are very often in lack of commercial space - the partially patented Store&Go+ technology enables the efficient utilisation of free space heights within the station infrastructure as a storage room for passengers luggage containers. The Store&Go+ system represents a solution, both technically and economically explored and examined for feasibility, which can be used not only in the planning of new stations, but also for existing buildings. Even open air installations at very small stations or in pedestrian zones are technically possible.

The central idea of Store&Go+ is that travelers (or any other passers not traveling) can check in their baggage in close proximity to high frequented parts of the station - like near the front entrance, or the exit of subway stations, or at taxi stand - quickly and easily into an automated luggage depot. In this way, relieved from the efforts of luggage future passenger increasingly may make use of the commercial centre of the railway station (e.g. restaurants, shops, travel agents, communication infrastructure, catering or the facilities for local supply, etc.). Before departure or before leaving the station the customers also easily can retrieve their luggage again.

Through the development possibly existing acceptance barriers were countered in upfront, too. So the Store&Go+ concept is a technological answer to meet all the demands and challenges of modern depot services. The system is also foreseen to be used as pick-up place for internet shopping in a self-service automatic unit.

3. ERGONOMICS AND THE USER’S PERSPECTIVE

In order to enable best user acceptance and customer-friendliness a prototype of the drop and pick-up station was built before detailed final construction steps were executed. More than 150 persons in all categories were interviewed and had to fill out structured questionnaires after testing different possible ways of operation.

Beside the cost for the individual storage period an easy handling of luggage lockers is the essential criterion for user acceptance. The handling consists of easy locating and supported lifting up the luggage and of self-explaining software dialogues. Also fast return of the luggage is essential. Most important is also the size of the lockers and the fact whether the luggage must be lifted or not.

Depending on the age and sex travelers have got different difficulties when they must lift luggage. For example about 50% of all female passengers with large luggage are not able or willing to lift it, about 20% are able or willing to lift it up to about one meter and only 30% are able to lift it higher.

For about 70% of all female and 40% of all male travelers storing luggage at low level is important. Also for 70% of all passengers above the age of 60 this is a must.
The time needed for storing and especially for getting back the luggage is another very important criterion for acceptance. More than 25% of the asked train passengers say the luggage returning must not need longer than one minute, more than 50% accept a time need between one and three minutes. The time need includes the whole process between coming to the locker until getting the luggage and leaving. Especially the subjectively felt time needed when passengers are in a hurry and they are nervous because of the approaching departure of their train is very important.

Many of today’s lockers are too small for usual luggage items. The width of many lockers is 33cm but 40% of all luggage items are bigger than this size. That means 40% of luggage items do not fit into normal lockers. Passengers either cannot store it or must use a much more expensive locker for huge items.

It was analysed, that about 80% of passengers staying more than 30min at the station think about using a short term locker for easier moving in order to use the station infrastructure like shops or bistros. For half of them the handling must be very quick and cheap.

4. THE STORE&GO+ SYSTEM SOLUTION

With regard to an utmost universal use the Store&Go+ system is designed for all the fields of railway transport, aviation and other hot spots of public places to be available for commuters, passengers and internet shoppers.

4.1 The focus on users healthiness and comfort demands

Core of an automatic and public luggage storage system must be an ergonomic, robust and tailored design, which fits to the needs of all kind of user groups. Any differences, such as age, gender and physically or mental health should be irrelevant. This means that an old person shall be able to deposit luggage, such as anyone using a wheelchair or a woman with a baby buggy.

The user interface principally has to meet the requirement of the general population. The dimensional design for physiological user heights and gripping areas directly result from the ergonomic body reference. These requirements for a physio-friendly and ergonomic operation have to be supplemented with barrier-free equipment for people with technical restrictions (disabled).

Also the cognitive system requirement factors have to be taken into account for the software and screen design of the user interface. Multilingualism in the user dialogs and the use of readily understandable pictograms and colours have to be applied even for colour-blind people. All operating functions must include logical (= the common expectation appropriate) operating dialogues with any function cancel option for all starting and operating steps with online help function.

All these specific human related requirements have to be added by standardized safety and comfort requirements, ranging from rounded bearing edges for protection against bruises to the exclusive use of simples controls which avoid users to be jammed.
4.2 The technical solution

As part of the research project Store&Go+ both the technical and economic feasibility has been proven. Finally the layout is characterized by the user friendly top and side loading philosophy and by a container volume adaptive handling technology.

The warehousing technology is based on proven and reliable automation concepts of industrial small part warehouses, which is combined with the innovative top and side loading container system to meet the conditions and demands as defined above. The key solution element is the cube adaptive container system which includes the covers (negative boxes) and cover locking.

![Figure 4. Store&Go+ container topping principle and technical construction](image)

Requested stability and robustness soon results in a materials selection of metal and the following frameworks specifications:

- **Framework of the resulting criteria for the container construction:**
  - large dimension: length: 100cm, width: 60cm
  - small dimension: length: 50cm, width: 60cm
  - max. luggage height 50 cm
  - resistant against vandalism and stealing
  - generally easy and simple mechanic for low maintenance cost

- **Framework of the cover criteria:**
  - The cover has to be secured in both directions (lifting and lowering of the lid) in case of swelling luggage (e.g. when it opens autonomously)
  - Automatic capping and uncapping takes place inside of the system in order to avoid bruising of the passenger.
  - An automatic control of the filling level is necessary.

- **Resulting criteria framework for the construction of the Pick Station:**
  - Pick station have to operate for the luggage deposit and the pickup.
  - Because of performance reasons a pick station (luggage input and output terminal) shall not serve more than 150 stock locations (bins).
  - Payment shall be able to be settled by use of vouchers, international credit cards and money. Instead of returning cash back vouchers may be issued.
  - The output orientation of the container shall be the same as for the input task. This allows easier gripping the handles or straps of the luggage.
  - A control of the container filling levels is realised by use of cameras and scales.
  - Mounted mirrors support visible inspection of the luggage placement in the container as well as the inspection of emptiness after outtake.
  - In case a container is not emptied completely by the customer, it must be stored again automatically.
The container must be transported underneath its supporting guides to the loading position in such a way, that no customer items are able to fall out. (e.g.: everything falling out of pockets has to fall into the container only.)

- Any danger of bruising or crushing has to be excluded.
- The handling height (minding disabled persons) is 40-60 cm.
- The max weight of luggage shall be about 35 kg per container.
- Initial height measurement or control of overhangs should be done before the move to the inner part of the station takes place. The control of emptiness or of maximal filling levels might be supported by pictures, which are taken within the station, where lighting conditions can be kept constant.

The automatic storage and retrieval system incorporates a lifting beam designed for optimum volume utilisation and maximum performance. The warehouse module may be installed across a length of up to 10m and can be used at building heights of up to 18m. It accommodates a load handling device for single-deep storage of the covered containers.

5. CONCLUSION

With the concept of Store&Go\(^+\) a concrete technical system has been developed for the innovative combination of deposit services for luggage and internet home deliveries in self-service robots. The systems is characterized by both a volume adaptive container technology as well as a novel luggage/parcel storage technology using racking systems and conveyors. This directly addresses not only quality objectives but also the performance targets and the users comfort.

Travelers will purchase more at the station whenever they can deposit hindering items. Store&Go\(^+\) enables station operators to meet this need and by means of offering a new attractive pickup service for internet shoppers they will increase the attractiveness of public transport in general, too. The easy to understand self-service round the clock function is not only a guarantee for good "usability" and user acceptance, but also facilitates urban mobility and stimulates the motivation to use public transport.

The Store&Go\(^+\) system addresses especially changing travel behaviours at railway stations, which increasingly will serve not only as enter or exit stations of public transport but also as centres for communication and internet shopping. The replacement of existing locker systems by Store&Go\(^+\) systems shall not only address the baggage depot service, but also has additional potential for use at Lost &Found departments. Furthermore, the new system is ready as pick-up station of internet shopping and for the daily needs of commuters and other travelers. The internet and its constant accessibility via smartphones and round the clock pickup stations will change the purchasing behavior of working people.

The Store&Go\(^+\) system is designed in modus to be implementable in adaptable sizes and scalable storage capacities at railway terminals, airports or other public hot spots like shopping centers.
6. REFERENCES


ANALYSIS OF THE LAND SPACE OCCUPIED BY TRANSPORTATION OPERATION: A CASE STUDY IN BRAZIL

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Abstract

Urban spaces occupied by transportation operation in two suburbs were mapped, quantified and analyzed with the aim of comparing the sustainability of their different land uses, considering traffic demand and historical development of the area. In this work two suburbs of Vitória City, in Brazil, were considered. The economic value of the urban space varies according to the demand and supply law, and it depends on the preference and needs of the population. Literature states that when transport infrastructure takes a significant plot of land, the boundaries of the occupied area tend to expand, and new areas are impacted by the settlements. As a consequence, more investments are necessary to provide urban services to attend population demands. By digital photo-interpretation of images, areas occupied by streets, avenues, and car parking areas were identified, quantified and compared with the whole area of the suburbs. Traffic volumes in the main streets of both suburbs were also compared with the area occupied by the road network. The results showed different infrastructure patterns and occupation, and the indication of unsustainable use of the urban space as concerns transportation.

Keywords: transport, land space, road length, sustainability

1. INTRODUCTION

Land use and transport are very much related to cultural aspects of the population. The culture of private transport leads to the urban sprawl, scattering residential areas under-served by public transport. In this case, automobile becomes a very attractive alternative of transport. This dependency caused by the occupation pattern is a result of the relationship land use and transport.

In order to improve mobility and accessibility, transportation policies usually lead to the construction of roads as a way to avoid the collapse of the transport system of cities. However, more space for the circulation leads to a more intensive use of the automobile, and consequently to increase in road demand, and so on [1].

Land use and development affect demand for transport, transport infrastructure affects land use, as well as mobility mechanisms affect the development and travel behaviour affects the environment. Thus it is necessary to adjust the city development with the urban road system, in order to ensure quality of life for the residents. In other words, it is important to control the transport demand that is originated by the growing population that occupies vast proportion of the territory and to adjust this demand to the existing or projected road system.

To improve the quality of life in cities aiming the sustainable development it is essential to relate land use planning with transport [2]. The built environment is thought to influence travel demand of the city according to occupation density, diversity of uses and its design given by builders [3]. Such factors affect trip rates and mode choice of residents. The interaction between the urban occupation, the capacity and the level of service of the existing street network was studied by [1] and [2].

This paper approaches the question of the land occupation with existing road network and its capacity to cope with the traffic demand. An inventory of the road infrastructure and the length of avenues, streets, public and private car parking of two suburbs of a metropolitan area in Brazil were carried out. Based on data collected by mapping these territories it was possible to quantify and analyze their spaces comparing them with the built environment.
2. STUDY AREA

For the purpose of this paper, a study examining two suburbs was conducted. The method used in this study was survey data, mapping the areas, computation of the level service of the main roads and analysis of the results.

Two suburbs of Vitoria City, in Espirito Santo, Brazil were considered in the study: Enseada do Suá and Mata da Praia. Enseada do Suá is located in the western part of Vitoria City, Brazil (red colour A in Figure 1). Its area is 1.25 km² and represents 1.34% of the City land (93.38 km)², represented in orange colour in Figure 1.

Figure 1 – Enseada do Suá (A) and Mata da Praia (B) suburbs

Mata da Praia suburb is located in Northern Victoria (red colour B in Figure 1), has an area of 1.35 km² and represents 1.45% of the City territory.

Digital photo interpretation of aerial photos with pixel 1m spatial resolution was used to identify the road surfaces and car parking areas in both suburbs. Manual heads-up on screen was carried out in the identification and computation of the areas. The types of road infrastructures which were mapped comprised streets, avenues, public and private parking.

The suburbs were chosen based on their similarity in area size and different land use. The Enseada do Suá suburb has many economic activities and services, while Mata Beach is mainly residential. Figure 2 shows Sua Bay.

The Enseada do Suá suburb emerged in the 70s as a result of a landfill held by the Company for Urban Development and the local government. Between 1971 and 1974 embankments were erected and a hydraulic fill of around 1,305,000 m² connected the flooding areas to the island of Vitoria City. Figure 2 illustrate the old and the actual landscape of Enseada do Suá.

Figure 2 – Enseada do Suá in 1960/70 and 2014.
Photos: Paulo Bonino and PMV
The initial aim to conquer new spaces was the decentralization of the city centre, and this policy drove the region of Enseada do Suá to a very attractive commercial centre [4]. Currently the suburb has a population of only 1,062 inhabitants of medium and high income classes for Brazilian standard [5].

As concerns the Mata da Praia suburb, in the early twentieth century it was a rural area, occupied by livestock, small animals and especially sandbanks (Figure 3). Its urbanization took place in 1952, and comprised a design of diagonal avenues with plots of land of approximately 400 m² for residential purposes and small commercial activities. The actual landscape is shown in Figure 4.

![Figure 3 – Mata da Praia land in the beginning of the 20th Century](Source: PMV)

Currently the Mata da Praia suburb has a high level of urbanization. Its population consists of 10,594 inhabitants, of medium and high income classes for Brazilian standard [5].

![Figure 4 – Mata da Praia suburb in 2013](Source: PMV)

Mata da Praia suburb is mainly residential. Along the beach the residents have a high standard of life and high incomes (Figure 4). It is slightly low the standard of life of the population living in the inner area, route of landing and takeoff of aircrafts of the nearby airport.

3. METHODOLOGY APPLICATION

Streets and car parking infrastructures were mapped, local traffic in the road network of both suburbs were allocated and the level of service of the main streets was determined. The proportion of the land used for transport purposes was computed and the level of service of the main roads was obtained. The results for each suburb were compared and the analysis was undertaken.

By definition, Level of Service (LOS) is the perception by the users of a traffic facility of the quality of service provided by a roadway. The Highway Capacity Manual [6] defines six LOS levels namely A, B, C,
D, E, F with A representing the most favourable driving conditions, and F representing the least favourable, characteristic of congestion.

In order to determine LOS a set of data was collected. The local authority transport sector provided data concerning flow taxes, saturation flow, and free flow speed.

Vitoria City network consists of 1,891 streets whose total length is 605 kilometres. The two suburbs considered in the study have 201 streets, of which 67 in Enseada do Suá and 134 in Mata da Praia. The suburbs have 22.67 and 29.50 street kilometres, respectively.

The road infrastructure in the suburbs together comprises a total area of 809,780 m², which represents 31% of their territory area. Car parking is included in the determination of the road infrastructure. The Enseada do Suá suburb has the highest occupation (486,858 m²) which represents 39% of its own territory area. Mata da Praia has 323,922 m² of road infrastructure, which represents 23% of this land. Table 1 shows the land use in both suburbs.

Table 1 – Land use in Enseada do Suá and Mata da Praia

<table>
<thead>
<tr>
<th>Suburb</th>
<th>Total</th>
<th>Road Infrastructure</th>
<th>Others</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m²)</td>
<td>(m²)</td>
<td>(m²)</td>
<td>Road Infrastructure</td>
</tr>
<tr>
<td>Enseada do Suá</td>
<td>1,234,537</td>
<td>486,858</td>
<td>747,679</td>
<td>39</td>
</tr>
<tr>
<td>Mata da Praia</td>
<td>1,394,500</td>
<td>322,922</td>
<td>1,071,586</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>2,629,037</td>
<td>809,780</td>
<td>1,819,265</td>
<td>31</td>
</tr>
</tbody>
</table>

Figure 5 shows the Enseada do Suá suburb with its road network in red. It is a suburb with many commercial and service activities, and a significant concentration of government offices (Town Hall, Courts, Navy, etc.). Its road infrastructure is compatible with the kind of activities that are developed in this area, which demand large and quick roads.

Enseada do Suá has large public car parking areas (Pope's Square, Science Square and Juremas Curve) which contribute to the amount of spaces of road infrastructure given in table 1. Additionally, it has also the largest private car parking in an open area in the city (Victoria Shopping) with 2,220 parking spaces, and an average traffic of 11,000 vehicles/day. Another significant road infrastructure is the toll plaza of the Third Bridge. Enseada do Suá suburb is connected to important avenues of the metropolitan region (N Sra Navegantes and Americo Buaiz), with high volumes of traffic.

Figure 5 – Road infrastructure in Enseada do Suá
Figure 6 shows the road infrastructure in Mata da Praia suburb.

Unlike Enseada do Suá, the network design of Mata da Praia has a rectilinear pattern of streets with similar characteristics. Most of the traffic flows in the East and West ends, where two important avenues Fernando Ferrari and Dante Michelini are connected to metropolitan corridors. Car parking areas are small and can be seen at supermarkets, hospitals, colleges, and at a municipal Park. In the East and along the coast, the Dante Michelini Avenue is a seaside promenade, equipped with bicycle lanes and public car parking locations around the region.

Table 2 shows the total number of vehicles and the corresponding level of service in intersections of the main roads. It also presents a resume of the traffic condition in the inner area of each suburb. The peak time of the local traffic was considered and the methodology [6] was used in the determination of the level of service. In the inner roads of Mata da Praia suburb, traffic is not so heavy and better level of service was found, varying from "A" (very good conditions of traffic flow), to "D" (limit to the condition of congestion). However, in the inner roads of Enseada do Suá suburb, traffic can be quite heavy, and the levels of service "C" and "E".

<table>
<thead>
<tr>
<th>Road Intersections</th>
<th>Mata da Praia</th>
<th>Enseada do Suá</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Ferrari – Adalberto Nader</td>
<td>5,020</td>
<td>840 to 1,830</td>
</tr>
<tr>
<td>Américo Buaiz – Desem Jones</td>
<td>4,380</td>
<td>1,261 to 3,810</td>
</tr>
<tr>
<td>Vehicle/hour</td>
<td>F</td>
<td>A to D</td>
</tr>
<tr>
<td>Level of Service LF</td>
<td>F</td>
<td>A to D</td>
</tr>
</tbody>
</table>

4. RESULTS AND FINAL COMMENTS

Historical aspects of occupation and urban planning in the suburbs contributed to the differences in land use, and therefore presented different characteristics and occupation. The settlements and the geometry of the road network influenced the traffic flow.

Despite the similarity in size, Mata da Praia offers 23% of its territory for the movement of vehicles, while a higher proportion of 39% was found in Enseada do Suá. The land occupation tends to be even greater since some spaces were not identified in the mapping, such as garages in basements, and car parking buildings.

Due to its residential characteristics, a significant proportion of the road network in Mata da Praia is used for residents in their movements in the suburb. According to [5], this suburb had 3,460 private households, being 99.2% occupied, and a population density of 3.06 persons per household. Local commerce, small shopping area, residences, schools and churches are the main travel poles in Mata da Praia. The level of service in the

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Table 2 – Traffic conditions
inner roads in Mata da Praia is quite good, varying from "A" to "D", however the main avenue (Dante Michellini) has the level of service "F", and characteristic of congestion.

The Enseada do Suá suburb has nearly double the road space of Mata da Praia, and relatively low occupation and population densities. In 2010, its total population was 1,062 inhabitants and only 785 households, of which 47.5% were occupied. This suburb has various offices, shopping, government buildings, commerce and some residences. The traffic is quite heavy, and a certain number of lorries and buses can be seen in this suburb not only to attend the cargo demand in the suburb, but also because it has an important avenue that links other areas of the city.

There should be equilibrium between the land occupation for transport purposes and the space necessary for city development. The over occupation of the territory with roads can cause limitations to expansion and development of the city. One of the consequences of such a limitation is the increasingly tendency of vertical buildings, as can be seen in Figures 2 and 4.

5. REFERENCES


AIRPORT CONGESTION AND CONGESTION CHARGES

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Abstract
This article discusses about today congestions problems and it introduces some instrument to deal with congestion. The paper deal with the third level airports slots allocation system and its effects on the congestion level at the airports. The main part of the article solves airport charges and mainly congestion charges that are one of the possible amendments into the coordination system, which is under review. Congestion charges are introduced in models regarding to the operators airplanes size, scheduling time, destinations distance and others. Conclusively there is consideration about advantages and disadvantages of congestion pricing or charges.

Keywords: congestion, charges, third level airport, coordination, allocation, airport slots

1. INTRODUCTION
During the past decade air transport congestion has increased in Europe and also in the U.S. The main reasons are growing demand, constrained capacity of infrastructure, and disruptions of scheduled services. The congestion is caused by the imbalance between demand and capacity is improved by the improvements of utilisation of existing capacity, physical expansion of infrastructure, and demand management. The first option has shown to have the limited effect. In many cases, the second option has been difficult or even impossible to be implemented in the short-term due to the various political and environmental constraints in terms of noise, air pollution and land use. The last, demand management has recently been considered as potentially viable option to relieve the congestion problem.

Figure 1 – Congestion at the airport
In addition to the institutional instruments, demand management at airports embraces the economic instruments such as congestion charging and auctions of slots (U.S) and allocation of airport slots. A central issue of the congesting charging relates to the estimation of marginal delay cost imposed by an additional flight to all other subsequent flights during congested period. In such a context, the additional flight has to pay its private cost of delay and a charge equivalent to the marginal cost of delays imposed on the subsequent flights during congestion period. This charge may increase the overall flight cost, and thus compromise its overall profitability. The current charging system at the European and U.S. airports is mainly based on the aircraft weights and has a little in common with the above concept of congestion charging. This article deals with the congestion charging at an airport. In addition to this introduction, the paper consists of these sections: demand versus capacity, congestion changing, inputs for charging and conclusions.

2. DEMAND AND CAPACITY

Airport congestion causes delays of flights. In general, delay is defined as the difference between the actual and scheduled time of being at the ‘referent location’. The threshold for either arrival or departure delayed flights is the period of 15 or more minutes behind the schedule [4].

At the European and U.S. airports, the congestion and delays have become their common (and inherent) operational characteristic. Following the statistics the proportion of delayed flights has been different in both regions. In Europe, this proportion has varied between 17% and 30% for arrivals, and 8% to 24% for departures. In the U.S., the proportion has varied between 22% and 40% for arrivals, and from 19% to 38% for departures. In general, more frequent delays have taken place at the U.S. than the European airports. Delays at airports are generally expressed as the averages per any flight and the averages per delayed flight (the total delay divided by the number of all or by the number of only delayed flights per period, respectively) (EUROCONTROL/ECAC, 2002; Federal Aviation Administration, 2002).

### Table 1 – Proportion of delayed flights

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Arrivals</td>
<td>Departures</td>
<td></td>
</tr>
<tr>
<td>Paris CDG</td>
<td>24.6</td>
<td>21.8</td>
<td>Chicago-O’Hare</td>
</tr>
<tr>
<td>London Heathrow</td>
<td>17.4</td>
<td>21.0</td>
<td>Newark</td>
</tr>
<tr>
<td>Frankfurt</td>
<td>30.8</td>
<td>18.9</td>
<td>Atlanta</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>25.7</td>
<td>23.2</td>
<td>NY-La Guardia</td>
</tr>
<tr>
<td>Madrid/Barajas</td>
<td>19.6</td>
<td>20.0</td>
<td>San Francisco</td>
</tr>
<tr>
<td>Munich</td>
<td>19.0</td>
<td>19.0</td>
<td>Dallas-Ft. Worth</td>
</tr>
<tr>
<td>Brussels</td>
<td>29.8</td>
<td>27.7</td>
<td>Boston Logan</td>
</tr>
<tr>
<td>Zurich</td>
<td>23.2</td>
<td>23.8</td>
<td>Philadelphia</td>
</tr>
<tr>
<td>Rome/Fiumicino</td>
<td>-</td>
<td>12.5</td>
<td>NY-Kennedy</td>
</tr>
<tr>
<td>Copenhagen/K</td>
<td>17.8</td>
<td>10.3</td>
<td>Phoenix</td>
</tr>
<tr>
<td>Stockholm/Arlanda</td>
<td>-</td>
<td>8.0</td>
<td>Detroit</td>
</tr>
<tr>
<td>London/Gatwick</td>
<td>19.6</td>
<td>24.3</td>
<td>Los Angeles</td>
</tr>
</tbody>
</table>

Dynamic interaction of the demand and capacity cause congestion at airports. The rate of such interaction is commonly measured by ratio of the intensity of demand and capacity (or the capacity utilisation ratio), which generally may take the values lower, equal or greater than one. Specifically, if the intensity of demand is equal to the capacity, this ratio is equal to 1.0 (or 100%). At the most European and U.S congested airports, contrary to the above-mentioned averages, this ratio often reaches or even exceeds the value 1.0 (100%), particularly during the short peak periods of an hour or quarter of hour, which suggests occurrence of the
significant congestion and delays (Federal Aviation Administration, 2001; 2002a). This gives rise to the question of managing this ratio and thus congestion below the threshold levels. In the short-term, this seems to be possible by the demand management, and particularly by using its economic instrument - congestion charging.

3. CONGESTION CHARGING

The theory of congestion pricing was developed for roads. Economists recognized that peak road usage is excessive because individual users do not take into account the delays imposed on all other users. Charging a congestion toll equal to the cost of the external delays each user generates will appropriately restrict peak use.

Congestion pricing follows the same logic when applied to airlines, with one important difference. Individual road users are atomistic; each driver is a small part of the total traffic on the road. By contrast, the airlines using a congested airport are typically nonatomistic; most individual airlines account for an appreciable share of the total traffic at the airport. This difference matters for airport congestion tolls, since a nonatomistic airline, unlike an atomistic driver, takes into account a portion of the congestion caused by each of its flights. Specifically, the airline considers the congestion each flight imposes on all the other flights it operates. In other words, it recognizes that scheduling an extra peak-hour flight will slow down its existing flights, possibly making the airline reluctant to add the flight.

The airline’s partial internalization of congestion means that the congestion externality is not as severe with airports as it is with roads. The overscheduling of flights is thus not as excessive as the overuse of a rush-hour freeway. As a result, airport congestion tolls can be less punitive than in the context of road congestion tolls. Just as with road pricing, the airport toll is based on the marginal congestion damage (MCD) from an extra flight, which equals the increase in operating cost for all the affected airlines plus the value of the lost time for their passengers. But because the airline internalizes some of its congestion, the toll does not equal the full MCD, as it would in the road case. It instead equals the MCD multiplied by one minus the carrier’s flight share, which equals the portion of the extra congestion that is not internalized by the airline. The formula thus charges the carrier only for the congestion it imposes on other airlines, exempting the congestion it imposes on itself.

For example, at an airport served by three identical airlines, each would pay a congestion toll equal to MCD times 2/3, reflecting the fact that 2/3 of the congestion from an extra flight falls on other carriers. MCD varies over the day, being high at peak hours and low (even zero) in the off-peak periods. Thus, the toll computed by this formula will vary over the day, disappearing when the airport is not crowded [10].

Up to date, despite being theoretically matured clear and warmly recommended by the academic economics and policy-making literature, congestion charging has still not found practical application at the congested airports. The main causes could be summarised as collision with the overall airport objectives including the lack of real cases, complexity of measurement, ambiguity of the concept and barriers within the industry.

Most airports worldwide have always intended to grow under given circumstances due to their internal (economic) as well as wider external (economic and political) regional and national interests. The growth has assumed attraction of as great as possible traffic. Under such circumstances, physical expansion of infrastructure capacity has always been used as the most feasible long-term solution for relieving congestion despite the various short-term social, political and environmental barriers. Consequently, the very rare, if any, airports have considered congestion charging as the viable short-term remedy. At the same time, the revenues from combined aeronautical and non-aeronautical charges have provided coverage of the airport operational costs and partly funding of investments [11].

4. INPUTS FOR CONGESTION CHARGING

Three groups of inputs are used in application of the proposed modeling procedure [10]:

- Data on the demand
  The hourly rates of the number of flights demanding service and their corresponding capacity at the airport for every day in calculation have been used for estimating congestion and delays. There are factors that have influence on the demand such a time of departure or arrive during the day, type of operator and its business model, connection flights, and
Capacity, for estimation of congestion and delays under given circumstances
Designation of the capacity is for the long discussion, but for this paper is important to list the factors influenced the capacity. They are: noise, ATC, runway, apron, terminal and others (political and demographical aspects, airport surroundings and competitors.

- The aircraft operating costs and airfares, for assessing profitability of the particular flights
  The aircraft operating cost have been expressed per block hour, in dependence on the seat capacity.

5. RESULTS AND OTHER ALTERNATIVES

Today, congestion charging is not real instrument how to fight with congestion. There are still some obstacles to introduce this. There are also some current systems for coordination of capacity and also for the trading or pricing it.

The main is airport slot allocation system and parts of it are: primary slot trading (U.S. market) and secondary trading (some EU airports). Within the slot coordination system there will be introduced some amendments, which could have positive impact comparable to congestion charging [5]. These are:

- Penalties and sanctions – sanctioning of an air carrier for providing misleading information and late hand back, in some circumstances coordinator shall withdraw series of slots instead of sanctioning.
- Slot reservation – it is an introduction of charging system where airport managing body uses this system with an aim to force carriers from late slot returning into the slot pool.
- Slot mobility and secondary trading – this part of the amended regulation consists of the secondary slot trading allowance, where slots could be exchanged and transferred within the regulation, with or without financial compensation.

Penalties and sanctions can improve coordinators work and make quicker and more flexible slot allocation. If there is information about a slot that the carrier is not able to operate, this information has to be sent to coordinator as soon as possible; so another carrier could get this slot. Sanctions should be established as a punishment for carrier who is a wrong-doer.

Another type of sanctioning rule says that the misuse of airport slots have to be sanctioned. Because of such circumventions, airport coordinators could sanction the airlines for misuse of their slots. This could help the better slot utilization and also to avoid congestion in the future.

Idea of slot reservation fee was introduced in one of the proposals for amendments within the current regulation.

Handing back slots in time (before the slot return date) would allow for an increase of slots reallocated, hence better use of capacity. It would also address the issue of over-bidding for slots or holding on to slots that will not be used to prevent competition. Slot reservation fee/deposit should be revenue neutral for airports and would reward the best airlines in class. No prior down payment for airlines – should be part of airport charges (could be a % of airport charges and would be offset against airport charges). The period between slot allocation and slot return deadline would allow airlines the flexibility to make adjustments and optimise their slots (with no liability). Airline liability would accrue from slot return deadline. Payment would be due on day of operation (or failed operation). Airlines would not be liable if unable to operate a slot due to circumstances outside their control.

6. CONCLUSIONS

The paper has dealt with modeling of the congestion charging at airports. At present, congestion charging has not been practiced at the airports worldwide despite many of them have already charged differently the services during the peak and off-peak periods.

The additional flight scheduled at the beginning of the congestion period has imposed the greatest marginal delays, and vice versa. The marginal costs have increased in proportion to the increasing of these delays on the one hand and the size of the succeeding aircraft on the other, and vice versa.

It is well known in the literature that congestion tolls by a congestible facility such as airport serve two purposes: first as a means for demand management and second as a source for investment financing. When carriers have market power, they will be able to internalize congestion costs – fully by a monopolist and partially by oligopolists – by setting a higher ticket price so that passengers will eventually bear the costs that
they impose on each other. Such practice by the carriers can well serve the purpose of demand management, as the higher ticket price will curtail demand and reduce congestion. Nevertheless, the internalization of congestion costs by the carriers would effectively deprive the airport of an important source of funds for its capacity investment, which may lead to financial problems for the airport.

Conventional economic wisdom suggests that congestion pricing would be an appropriate response to cope with the growing congestion levels currently experienced at many airports. Several characteristics of aviation markets, however, may make naive congestion prices, equal to the value of marginal travel delays, a non-optimal response. This paper has developed a model of airport pricing that captures some of these features. The model reflects that airlines typically have market power and are engaged in oligopolistic competition, and that a part of external travel delays that aircraft impose are internal to an operator and hence should not be accounted for in congestion tolls. We have also briefly considered the issue of policy coordination between airports.

This paper analyzes pricing and slot-allocation mechanisms when profits are important to an airport, owing to budget constraints or profit maximization. We find that pricing and slot trading/slot auctioning do not lead to the same results. Total traffic is higher under slot auctions than under congestion pricing. Furthermore, if airport profits matter just marginally, then slot auctions will outperform pricing in terms of achieving a higher objective-function value. On the other hand, if airport profits matter sufficiently highly, which mechanism is better is then very much dependent on parameter values. In particular, pricing may be strongly preferred over slot auctions for certain parameter values (specially when airlines are very asymmetric).

Congested airports analysis suggests that strategic behavior on the part of the airport that cares about its profit can have a significant bearing on the comparison of price vs. slot-based approaches to congestion management, depending on what is asked from the airport, and what matters to the airport. This is because, for some parameter values, one mechanism may lead to larger airport profits while at the same time reducing airlines’ profits and the value of the overall objective function. Hence, if a regulator asks airport managers to maximize a certain objective function, but the choice of a flight-allocation mechanism is left to the airport, there may be social welfare losses, with the extent of welfare losses depending in general on cost and demand parameters. Paper results thus imply that, if airport profits matter, then there is no simple solution as to which mechanism should be employed or implemented.

7. ACKNOWLEDGEMENTS

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8. REFERENCES


MANAGING DISRUPTION RISKS IN THE GLOBAL SUPPLY NETWORKS – A TRANSDISCIPLINARY APPROACH

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Abstract

Supply chain risk can be seen as any event that might affect continuity of materials and information flow. The risks within the supply chain occur when unexpected events disrupt the flow of materials on their way from initial suppliers to the final customers. In the broad perspective risk exists as a concept embracing two major components: consequences of an activity and associated with it uncertainties. The objective of this paper is to come up with a new framework of disruption risk management for the global supply networks. The core idea of the overall concept is based on the transdisciplinary approach.

Keywords: risk, disruption, vulnerability, resilience, supply chain

1. INTRODUCTION

Risk is a fundamental aspect of human life, affecting every activity of society and world events. As a consequence it should be managed both effectively and efficiently to protect people from any harm and allow company to develop and progress. Nowadays, risk and uncertainty are frequently magnified in large-scale technological systems, as well as service systems. Companies that successfully address problems in such fields as future product designs, resource availability, market changes, and in engineering systems will dominate in the today competitive world.

There are a lot of risk definitions typical of a given knowledge discipline. Based on The Business Dictionary [6] we can distinguish:

- Hazard risks – a probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through preemptive action.
- Financial risks – the probability that an actual return on an investment will be lower than the expected return. Financial risk is divided into the following categories: Basic risk, Capital risk, Country risk, Default risk, Delivery risk, Economic risk, Exchange rate risk, Interest rate risk, Liquidity risk, Solvency risk, Operations risk, Payment system risk, Political risk, Refinancing risk, Reinvestment risk, Settlement risk, Sovereign risk, and Underwriting risk.
- Operational (industrial) risks – the possibility that due to a certain hazard in product there will be an negative effect to a certain magnitude.
- Insurance risks – A situation where the probability of a variable (such as burning down of a building) is known but when a mode of occurrence or the actual value of the occurrence (whether the fire will occur at a particular property) is not. A risk is not an uncertainty (where neither the probability nor the mode of occurrence is known), a peril (cause of loss), or a hazard (something that makes the occurrence of a peril more likely or more severe).
- Trading risks – The probability of a loss or drop in value. Trading risk is divided into two general categories: (1) Systemic risk affects all securities in the same class and is linked to the overall capital-market system and therefore cannot be eliminated by diversification. Also called market risk. (2) Nonsystematic risk is any risk that isn't market-related or is not systemic. Also called nonmarket risk, extra-market risk, or unsystemic risk.
- Occupational (workplace) risks – Product of the consequence and probability of a hazardous event or phenomenon. For example, the risk of developing cancer is estimated as the incremental probability of
developing cancer over a lifetime as a result of exposure to potential carcinogens (cancer-causing substances).

The keywords needed to describe the disruption risks are [based on 6, 29]:

- Exposure – the state of being susceptible to an element (a risk source), an action (e.g. an attack), or an event (e.g. a natural catastrophe).
- Threat – (a) one that is regarded as a possible danger; a menace; (b) something that is a source of danger. (c) negative event that can cause a risk to become a loss. A threat may be a natural phenomenon such as earthquake, flood, storm, or man made incident such as fire, power failure, sabotage, etc.
- Hazard – a possibility of being injured or harmed.
- Disruption – (a) an act of delaying or interrupting the continuity, (b) an event that results in a displacement or discontinuity.
- Security – (a) something that protects or makes safe; defense; (b) the protection of data to ensure that only authorized personnel have in access to computer files (Computer Science).
- Vulnerability – degree to which people, property, resources, systems, as well as cultural, economic, environmental, and social activity are susceptible to threat, harm, degradation, or destruction of being exposed to a hostile agent or factor.
- Resilience – ability of an equipment, machine, or system to absorb and withstand the disruption impact, and to still continue providing an acceptable level of service.

2. QUANTITATIVE RISK MEASURE

In the paper [3] Aven reviews and discusses some key concepts of risk analysis and risk management. He discussed the following concepts on risk:

- Risk is equal to the expected value
- Risk equals uncertainty
- Risk is equal to an event
- Risk is a probability or a probability distribution
- Risk equals expected disutility
- Risk is restricted to the case of known probabilities
- Risk based on subjective probabilities is the same as risk perception
- Objective risk exists
- Risk is determined by the historical data
- Risk relates to negative consequences
- Risk and probability cannot be determined in case of large uncertainties
- There are large inherent uncertainties in risk analyses
- Risk acceptance criteria contribute to obtaining a high safety standard
- ALARP (As Low As Reasonably Practicable) can be verified by cost-benefit analyses
- The cautionary/pre-cautionary principles and risk management cannot be meaningfully integrated.

For the risk analysis and risk management we need one comprehensive quantitative definition of risk. The most convenient for this objective seems to be so called Kaplan-Garrick triplet [15]. According to this concept risk is equal to the triplet [16]

\[
\text{Risk} = (s_i, p_i, c_i),
\]

where \( s_i \) is the \( i \)-th scenario, \( p_i \) is the probability of that scenario, and \( c_i \) is the consequence of the \( i \)-th scenario.

To build the model (1) we need to quantify the answer in reference to the three following questions:

1. What can go wrong (what can happen – identifying the possible scenarios \( s_i \))?  
2. How likely is it to go wrong (how likely is that to happen – assessment of scenarios probabilities \( p_i \))?  
3. What are the consequences of going wrong (if it does happen, what are the consequences – estimation of the scenarios consequences \( c_i \))?  

...
The help by answering of these questions is given by W. L. Oberkampf [18]:

1. What can go wrong?
   - Identify initiating events (abnormal and hostile environments)
   - Construct plausible event and fault trees (scenarios)

2. How likely is each plausible scenario?
   - Use experimental and operational data to characterize probabilities
   - Use expert-opinion to characterize probabilities
   - Assume independence/dependence between events/subsystems
   - Use M&S (Modeling and Simulation) to predict outcomes of each scenario
   - Compute probabilities of each scenario

3. What are the consequences of each scenario?
   - Merge probabilities and adverse impact to obtain a consequence for each scenario or
   - Deal directly with computed probabilities of each scenario

3. RISKS IN SUPPLY CHAINS

Supply chain risk can be seen as any event that may affect continuity of the materials and information flow. The risks observed within the supply chain occur when unexpected events disrupt the flow of the materials on their way from the initial suppliers to the final customers. Thus the vulnerability of a supply chain reflects its exposure to disruption (major threat).

A disruption to the supply chain can have widespread effects, with Hendricks and Singhal [11] noting that shareholder return typically falls by 7–8% on the day that a disruption is announced, operating income falls by 42% and return on assets is down by 35%. There are basically two kinds of risk to a supply chain:

- internal risks that appear in normal operations, such as late deliveries, excess stock, poor forecasts, financial risks, minor accidents, human error, faults in information technology systems, etc;
- external risks that come from outside the supply chain, such as earthquakes, hurricanes, industrial action, wars, terrorist attacks, outbreaks of disease, price rises, problems with trading partners, shortage of raw materials, crime, financial irregularities, etc.

Jüttner [14] observed that the most important factor which seems to increase the supply chain vulnerability is the globalization (reported by 52% of managers). The basic sources of risk associated with globalization are the following [30]:

1. Risks from working in a region that is less familiar and more distant from the organization’s usual operations. These include reduced control over remote sites, cultural differences, variable levels of skills, language problems, legal systems, political instability, unstable economic conditions, changing costs, rapidly changing conditions, different levels of commitment to quality, and so on.
2. Risks of moving materials through longer supply chains. These include the inherent risks of extended journeys, crossing international borders, meeting different cultures, extended lead times, more stock in transit, more handling, the need for bigger order quantities, greater chance of loss, obsolescence of products with short life cycles, and so on.
3. Unexpected barriers to trade, such as:
   a. product design limiting demand, with different regions demanding different types of product, a product not lending itself to global operations, or customers simply not liking products;
   b. practical difficulties making it impossible to meet demand — such as protectionist government policies, problems at national frontiers, inadequate infrastructure, missing technical skills, or other cultural and economic differences.

Nine principles for efficient risk management developed by the Risk Intelligent Agency of Deloitte [9] are:

1. Develop common definitions of risk that encompass threats to and opportunities for mission advancement.
2. Use a common risk framework supported by appropriate standards to manage risks throughout the organization.
3. Define and delineate key roles, responsibilities, and accountabilities related to risk management.
4. Encourage cross-functional, agency-wide risk management.
5. Ensure that risk management practices are appropriately transparent.
6. Locate primary responsibility for driving the risk management program with senior executives.
7. Hold program managers responsible for achieving their missions and for managing risk within the risk management framework.
8. Engage key support functions in organization-wide risk management.
9. Provide assurance to external stakeholders that risks have been identified and are being managed.

4. CONCEPT OF THE DISRUPTION RISK MANAGEMENT IN THE GLOBAL SUPPLY NETWORKS

The main idea of the disruption risk management concept for global supply networks is shown in Figure 1. The two-dimensional model of a logistic system provides for both operational perspective and risk perspective. Managing disruption risk consist of two phases: the disruption occurrence management and the disruption impact management. From the risk perspective diverse external risk sources can generate threats and hazards, which come up against security barriers. This barriers neutralize the most of the threats and hazards, but some of them succeed in getting through and creating an exposure to the logistic system. When the vulnerability of the logistic system is higher than the resilience, then it comes to disruption [28]. The severity of this disruption and its consequences (resources loss and break down of functions) depends on the logistic system resilience.

![Two dimensional model of logistic system](image)

**Figure 1** – Two dimensional model of logistic system

Typical disruption time history could be divided into four phases (Figure 2):

A. Pre-disruption period – SECURITY
   a. Prediction and anticipation of disruptive events (threats and hazards)
   b. Monitoring and recognition of unanticipated disruptive events
   c. Reduce disruption assurance (prevention and protection)

B. During disruption – SURVIVABILITY ($T_S$)
   a. Resistance ($T_{S1}$)
      i. Absorb disruption impact
      ii. Withstand disruption shocks
   b. Bounce back ($T_{S2}$)
      i. Retain and sustain structure and functions
      ii. Reorganize structure and processes (redundancy or self-organization)

C. After disruption (short time perspective) – RECOVERY ($T_R$)
   a. Damage removing ($T_{R1}$)
   b. Repair and restoration ($T_{R2}$)
D. After disruption (long time perspective) – IMPROVEMENT (T₃)
   a. Learning from disruption and adaptation to harmful environment
   b. Reengineering (redesign of structure and processes)

The phase A belongs to the discipline of Security Engineering [1] and the phases B, C, D to a new, emerging discipline of Resilience Engineering [12, 21, 24, 25, 30].

5. CONCLUSIONS

- Efficient management of disruption risks in the global supply networks needs to be seen as transdisciplinary approach, from the financial, social and engineering point of view.
- Managing disruption risk consist of two phases: the disruption occurrence management (security area) and the disruption impact management (resilience area).
- Learning from the cases of disruption and adaptation to harmful environment can constitute the most important conditions of achieving the supplying continuity in a long time perspective.

6. REFERENCES

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HOW RISK MANAGEMENT IN LOGISTICS CHANGED IN JAPAN AFTER A NATURAL DISASTER

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Abstract

The Great East Japan Earthquake in 2011 have had a great influence on logistics. The purpose of this research is to make clear what kind of new risk management procedures were introduced in procurement, production, and sales. A questionnaires’ survey was conducted on a large number of big Japanese companies. The results of the survey shows that many companies have introduced various measures such as the diversification of both procurement and production, in-house operations in production, common use and standardization of parts, revisions to inventory levels, reinforcement of transparency in supply chains.

Keywords: risk management, resilience, transparency of supply chain

1. INTRODUCTION

Following the Great East Japan Earthquake, a number of problems were identified related to Japan’s logistics network. There were serious shortages of products in the disaster area, and people trapped in this zone were unable to obtain the items they needed. Furthermore, supply chains were disrupted, cutting off the supply of raw materials, parts and finished products needed by manufacturers, forcing them to halt production activity, and creating shortages of many products in retail stores. Following the quake, companies became keenly aware of the importance of addressing risks related to their logistics systems, and many took steps to revise these systems.

Companies have discussed the issue of how to manage this sort of risk, and offered a number of proposals for dealing with the question. These can be broadly divided into two categories: those that provide systems or methods of dealing with risk, and those that set aside capital or material goods to draw upon in times of risk. The systems and methods developed to deal with risk factors such as natural disasters can be further broken down into those that seek to predict disasters, those that seek to prevent or limit the scope of disasters, those that seek to disperse or share the burden of disasters, those that seek to control the impact, and those that respond to disasters and deal with the aftermath.

In considering ways to develop resilient logistics systems, one of the first points that became apparent after the March 2011 disaster was that the effort to develop efficient, lean supply chains (lean SCM) was counterproductive. A great many papers and studies have addressed the need for flexible, redundant and resilient logistics systems. Furthermore, with respect to the development of information systems, many papers have examined the importance of comprehensive systems that cover the entire supply chain. Existing papers that discuss measures taken by companies to deal with logistics-related risk, in the wake of the earthquake and tsunami, have been based on an analysis of questionnaires, and particularly surveys of the steps taken to adjust procurement methods. A number of magazine articles have also appeared, dealing with specific examples of steps taken by a particular company.

In this paper, we will consider the ways in which Japanese corporations have adjusted their basis for evaluating logistics systems, following the Great East Japan Earthquake. In the past, the top priority has been
to achieve management and cost efficiency. In 2013, we conducted a survey of leading corporations in Japan to identify current trends, and to determine whether companies are now evaluating logistics systems based on a broader range of considerations, including risk-related response and other overall factors. In addition, we surveyed the risk-management measures that each company has introduced in its logistics activities, covering procurement, production and sales-related logistics, and analyzed specific examples of such risk-management measures.

2. OUTLINE OF THE SURVEY

The survey was conducted by mailing out questionnaires to companies in June 2013, slightly more than two years after the Great East Japan Earthquake. The survey was mailed to 1,287 companies listed on the First Section of the Tokyo Stock Exchange, covering a wide variety of industry sectors including agriculture, forestry & fisheries, construction, manufacturing, warehousing & transport, wholesale and retail commerce. Responses were received from 123 companies, or 9.6% of those targeted. Of these, the largest number of companies came from the manufacturing sector (70), followed by retailers (16) and warehouse/transport operators (15). Dividing the respondents on the basis of annual sales revenues, 44 companies had annual sales of between 100 billion yen and 500 billion yen, 32 companies had sales of less than 50 billion yen and 18 had annual sales of over 1 trillion yen.

A very large percentage of the companies were directly affected by the Great East Japan Earthquake, with 83 respondents (67.5%) reporting a significant impact on their supply chain as a result of the disaster. Of those who reported disruptions, about half indicated that it took about a month for business activities to return to normal, following the earthquake.

3. CHANGES IN RISK MANAGEMENT CONSIDERATIONS

3.1 Logistics Disruption Following the Earthquake

When asked whether the earthquake exposed weaknesses in their logistics systems and the related risk management system, an equal number (35.4%) responded that it did expose weaknesses, and that it did not expose weaknesses. The others answered that they were not sure. However, among companies which responded that their risk management systems prior to the earthquake were "adequate", only 13.3% experienced problems in the wake of the earthquake. This illustrates the importance of taking measures to deal with risk in the event of a natural disaster.

3.2 Changes in Company Approaches to Risk-Management

Analysis of the survey helps to shed some light on the changes in company attitudes towards risk management following the earthquake, compared with their stances prior to the disaster. The survey asked questions that sought to determine the degree of importance that companies placed on risk management, relative to efficiency, and how perceptions of this tradeoff changed following the earthquake.

The results are summarized in Table 1, which compares the stance that companies took prior to the disaster (on the vertical axis) with the stance they adopted following the disaster (on the horizontal axis). A comparison of the figures makes it clear that companies greatly altered their stance on risk management, and its importance to a logistics network, in the wake of the disaster. Of the 115 companies that provided meaningful responses to the questions, the majority categorized their stance prior to the disaster as "placing highest priority on management efficiency, with virtually no consideration of the system’s responsiveness to risk factors." However, following the earthquake there were many respondents who changed their stance to "placing priority on management efficiency, but also giving due consideration to risk responsiveness." Of the companies that placed no importance on risk management prior to the earthquake, 27.0% of companies indicated that they gave consideration to risk management factors in developing logistics systems, following the earthquake. A further 27.0% described their stance as "placing priority on management efficiency, but also giving due consideration to risk responsiveness" both prior to, and after the disaster.

Furthermore, among companies that described their stance prior to the earthquake as: "placing priority on management efficiency, but also giving due consideration to risk responsiveness," 21.7% indicated that they intensified their focus on risk management following the disaster. These companies described their post-quake stance as: "giving full consideration to both management efficiency and risk management factors."
As Table 1 shows, 50.4% of the respondents indicated that they gave risk management factors a greater emphasis following the Great East Japan Earthquake than they did prior to the disaster. Furthermore, only 13.9% stated that they gave full consideration to risk factors, prior to the quake. This confirms that companies have been placing more emphasis on risk management considerations in the development of logistics systems, since the disaster.

<table>
<thead>
<tr>
<th>Stance prior to the earthquake</th>
<th>Stance following the earthquake</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placing highest priority on management efficiency, with virtually no consideration of the system’s responsiveness to risk</td>
<td>Placing priority on management efficiency, but also giving due consideration to risk responsiveness</td>
<td>Giving full consideration to both management efficiency and risk management factors</td>
</tr>
<tr>
<td>10</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>8.7%</td>
<td>27.0%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Placing priority on management efficiency, but also giving due consideration to risk responsiveness</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>27.0%</td>
<td>21.7%</td>
<td></td>
</tr>
<tr>
<td>Giving full consideration to both management efficiency and risk management factors</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>13.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>62</td>
</tr>
<tr>
<td>8.7%</td>
<td>53.9%</td>
<td>37.4%</td>
</tr>
</tbody>
</table>

Table 1 – Changes in Companies’ Responsiveness to Risk Following the Earthquake

3.3 Relationship of Companies’ Industry Sector to their Risk Responsiveness

There were significant differences visible in the attitude towards risk management depending on the industry sector of the respondent. A large percentage of companies in the retail and wholesale commerce sectors noted that prior to the earthquake, they had put heavy emphasis on efficiency, and paid little attention to risk responsiveness. However, following the disaster a high percentage stated that they were now giving greater consideration to risk management issues. On the other hand, of the companies which stated that they had given adequate consideration to risk even before the earthquake, many were involved in warehousing and transport, or were manufacturers of vehicles and other transportation equipment.

3.4 Business Continuity Planning

Some 35.8% of the companies surveyed replied that they already have business continuity plans (BCPs) in place, while 27.6% said that they already had business continuity plans, but were currently in the process of revising them. Meanwhile, 16.3% stated that following the earthquake they recognized the importance of establishing BCPs, but that they were still in the process of formulating their plans. A further 14.6% plan to formulate BCPs in the future. Only 5.7% said that they did not plan to establish a BCP. Of the companies that indicated a responsiveness to risk even prior to the earthquake, a large percentage already had business continuity plans. However, many indicated that following the massive disruption caused by the Great East Japan Earthquake, they were forced to make changes to their BCPs to reflect the existence of even greater risks.

4. RISK MANAGEMENT IN PROCUREMENT AND PRODUCTION

4.1 Risk Management in Procurement Activities

Of the companies surveyed, 66.4% reported specific measures taken to address risks related to procurement. A large percentage of companies have taken steps to manage these risks by diversifying their procurement sources and using more than one supplier, as shown in Table 1. For products sourced in Japan, 56.2% of respondents indicated that they have identified multiple suppliers, whereas in the case of goods procured from overseas, 41.1% of respondents have diversified their suppliers. Even in cases where a single supplier is used, 12.3% have asked vendors to produce individual items at more than one factory. For example, since the late 1990s automakers have been gradually reducing the percentage of any individual product that they procure from a single primary supplier, and establishing multiple procurement routes.
According to our survey, 31.5% of respondents have taken steps to clarify the details of their supply chain, identifying not only their own direct suppliers but also identifying secondary and tertiary levels of upstream production, which supply items to their suppliers.

For example, Toyota Motor Corp. has asked all primary suppliers to provide them with a full, detailed diagram showing the sources of all items, in some cases extending to sixth- or even seventh-level parts or materials suppliers. This information on the overall supply chain is stored in a database at each Toyota factory. The company makes inquiries about each part or product, and whether there is an alternate factory or facility that can make the same product if the first-choice factory is closed due to some disaster. Parts that can only be provided by one factory or location, are then identified as "parts at risk". Similarly, Nissan Motor Co., Ltd. has established a database containing the production designs and molds for every single component used in every Nissan vehicle. This provides a structure that would allow the company to quickly move production to an alternate location in case of an emergency.

26.0% of respondents have taken steps to standardize components, making it easier to switch to alternative sources of supply. In addition, 9.6% have asked their suppliers to increase the volume of inventory held in stock. In the case of items that are difficult to produce at alternative plants, such as electronic components and cast metal items in particular, they are asking suppliers to maintain inventories at levels that would ensure a supply of these items is available even if the plant that makes them is temporarily closed.

In evaluating the specific measures companies have taken to respond to risk, it is apparent that companies may be taking steps to diversify their suppliers for reasons that have nothing to do with risk management. However, a large percentage of the companies that give ample consideration to risk management also make the effort to clarify the details of its entire supply chain.
4.2 Risk Management in Production Activities

71.3% of respondents indicated that they have taken specific steps to address risks related to their production activities. The steps they have taken are categorized in Figure 1. Among the measures taken, the most common (identified by 50.0% of respondents) was to introduce measures that protect production facilities from earthquake damage. The next most common measure was to re-evaluate the production structure and make adjustments, such as producing key products at more than one factory. Measures to diversify production sites were cited by 48.4% of respondents, with 19.4% indicating that they are building new production capacity in order to permit this sort of diversification. Another 25.8% indicated that they have moved some production activities to overseas plants, in order to diversify their production network.

Following the Great East Japan Earthquake, a great many manufacturers have revised their production structures by dispersing production activities to numerous locations. Particularly in the case of important products, they have established separate facilities in eastern and western Japan, each capable of producing the same products. For example, manufacturers of medical equipment and medical products bear a particularly heavy responsibility to maintain the supply of products and not encounter shortages if their production facilities are temporarily shut down. Therefore many companies in this industry have revised their production structure.

A large percentage of companies – 32.3% – noted that they have formulated plans that allow production to be shifted to alternate factories if necessary. After the Great East Japan Earthquake, some manufacturers were able to quickly resume production even though their facilities in Tohoku region (north-east area of Japan) were destroyed, because they had alternate sites to which they could shift production activity. Using these companies as an example, many manufacturers have begun to set up alternative production sites. For example Toto Ltd. – a manufacturer of ceramic sanitary fixtures – is setting up alternative factories in Japan at sites a considerable distance from one another, each making the same products. In some cases the alternate production sites will be established outside Japan. As part of its business continuity plan, Toshiba Corp. is identifying alternative production sites for each product. For example a new plant in Malaysia will be capable of taking over the production of automotive transistors from Toshiba’s existing plant in Thailand.

A smaller number of manufacturers – 8.1% – have taken steps to increase the ratio of in-house production. Zebra Co., Ltd., a manufacturer of pens and other writing implements, is planning to centralize production activities. Following the Great East Japan Earthquake, the company faced disruption in its production supply chain because a majority of production was contracted out. In-house production facilities were brought back on line much more quickly. The company concluded that risks can be reduced by making more things in-house, rather than outsourcing production.

22.6% of respondents said that they have taken steps to increase inventories of raw materials and components. Following the earthquake, many factories were restored to operability but were unable to resume production because they did not have any raw materials or components, or were unable to procure them. Therefore, many companies are increasing the volume of materials held in inventory at production plants. In addition, 8.1% of respondents have taken steps to narrow down the range of products they manufacture. Following the Great East Japan Earthquake, a particularly large number of food product manufacturers, among others, were able to boost production capacity quickly by focusing on a narrower range of products.

5. RISK MANAGEMENT IN SALES LOGISTICS ACTIVITIES

Of the companies surveyed, 71.6% indicated that they have taken specific measures to address risk related to their sales logistics activities. As Figure 2 shows, 39.7% have cooperated with the transport companies to whom they contract logistics activities, and confirmed that these vendors are improving their responsiveness to risk. The largest percentage – 35.6%, indicated that they have plans to cooperate with logistics contractors in the event of a disaster, in efforts to address the risk.

Since a large percentage of respondents depend on transportation companies to handle their actual distribution activities, it is important for the company and its distributor to work together in planning measures to address risk. In a majority of cases, though the product shipper currently depends on their contracted distributor to take measures to address risk. Therefore, if the distribution company is not able to respond to the situation in the wake of a disaster, their customers will probably be stuck. Meanwhile, 31.5% of respondents indicated that they are strengthening their backup capabilities for distribution-related
information systems. Measures include the use of cloud computing and the establishment of more than one computer information centre. A large percentage of companies have taken such measures.

Companies are also taking steps to diversify their logistics facilities, or are setting up alternate distribution centres that can take over operations when necessary. 26.0% of respondents have diversified their use of facilities, and 26.0% have set up alternate logistics centres.

Since the earthquake, however, companies have begun to recognize the risk that consolidation invites. Many are now taking steps to disperse their distribution centers. Even companies that have already established large-scale distribution centers on the ring road system surrounding Tokyo have begun to set up other facilities to disperse distribution, particularly in inland sites that will not be affected by the soil liquefaction and subsidence seen in areas along the coast. In this way, they hope to reduce disaster-related risks. Retailers also have been dispersing distribution centers. Since the earthquake, convenience store operators have been pushing for greater dispersal of distribution sites to reduce risk. For example, the company that supplies boxed lunches for Seven-Eleven Japan Co., Ltd. has set up several logistics centers, and introduced molding machinery to make rice balls more quickly and with higher quality.

Another convenience store operator, Familymart Co., Ltd., is reviewing its distribution network. Over the next three years the company plans to increase the number of distribution centers it operates by ten, from 91 as of the end of fiscal 2011. The increase in facilities is expected to reduce capacity utilization levels from 92%, at present, to around 84%. However, this is intended to allow the company to use spare capacity during a natural disaster, in order to deliver as much relief supplies as possible to stores within the disaster area. In addition, the company intends to increase the number of facilities with refrigeration centers, which are used mainly for handling fresh boxed lunch items. These efforts will also reduce the average distance that items must be transported, so that in times of emergency, alternate centers can more easily supply stores in the disaster area.

Following the Great East Japan Earthquake, many distribution centers in the area were damaged and companies had to ship their products in from distribution sites in the Kanto region (eastern half of Japan), or some other nearby prefecture. In order to adjust to such an emergency situation quickly and smoothly, it is

Figure 2. Risk Management Measures Related to Sales Logistics

<table>
<thead>
<tr>
<th>Measure</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversification of distribution centers</td>
<td>26.0%</td>
</tr>
<tr>
<td>Establishment of alternative distribution centers</td>
<td>26.0%</td>
</tr>
<tr>
<td>Increase in sales inventories</td>
<td>11.0%</td>
</tr>
<tr>
<td>Internalization of logistics activities</td>
<td>9.6%</td>
</tr>
<tr>
<td>Relocation of distribution centers to less risky locations</td>
<td>11.0%</td>
</tr>
<tr>
<td>Inclusion of earthquake-resistant design in distribution facilities</td>
<td>20.5%</td>
</tr>
<tr>
<td>Reconsideration/revision of automated operations</td>
<td>8.2%</td>
</tr>
<tr>
<td>Establishment of emergency power supply systems</td>
<td>20.5%</td>
</tr>
<tr>
<td>Establishment of fuel stockpiles</td>
<td>9.6%</td>
</tr>
<tr>
<td>Backup measures for information systems</td>
<td>31.5%</td>
</tr>
<tr>
<td>Consideration of alternative transport methods (rail, sea, etc.)</td>
<td>16.4%</td>
</tr>
<tr>
<td>Joint transportation activities</td>
<td>21.9%</td>
</tr>
<tr>
<td>Diversification of logistics contractors</td>
<td>20.5%</td>
</tr>
<tr>
<td>Evaluation of logistics contractors’ risk-responsiveness</td>
<td>39.7%</td>
</tr>
<tr>
<td>Cooperation/communication with logistics contractors</td>
<td>35.6%</td>
</tr>
<tr>
<td>Standardization of warehouse transport equipment</td>
<td>5.5%</td>
</tr>
</tbody>
</table>
important to identify specific "alternate centers" to take over for each center that is damaged. One food wholesaler whose distribution center was unusable after the earthquake received purchase orders at its Kanto facility that were 2-3 times the normal size, and in some cases, up to ten times the typical amount. For the company’s 300 distribution centers in Japan, a business continuity plan was established that specified alternate sites for every process. If any center becomes unusable, or unable to handle the full required volume of activity, the continuity plan identifies the facility that is responsible for taking on that burden. One general merchandise store operator set up an alternate distribution center in a location outside Osaka to take over operations if the main center in Osaka should become unusable.

Furthermore, measures are being taken to make the logistics centres themselves more durable. 20.5% of respondents have taken steps to make the buildings more resistant to earthquakes, or installed backup power generation facilities. At a recently built industrial park in Tokyo, which is home to large-scale distribution facilities, a large percentage of the buildings feature earthquake-resistant designs. This was one of the key factors cited as a requirement by many of the companies that have moved into the facility. Meanwhile Japan’s largest mass merchant and retail conglomerate, Aeon, is introducing on-site power generation facilities at all 40 of its distribution centres in Japan. Although the total percentage of respondents that have increased inventory levels is a relatively low 11.0%, such measures are increasingly being adopted for stocks of items that are essential for daily life.

Pharmaceuticals manufacturers, in particular, have begun to re-evaluate the size of their inventory stockpiles. One manufacturer doubled inventories of all products to ensure that, in principle, the company would have a six-month supply even if all production stopped. The six-month supply is intended to ensure that all demand can be met until the production line can be restarted. In addition, the company has taken steps to reduce risk by ensuring that in addition to its own distribution center, it can also use the distribution facilities of another manufacturer in another prefecture, in times of emergency.

9.6% of respondents said that they have increased stockpiles of fuel at their distribution centres. A large percentage of logistics companies have installed tanks to contain stockpiles of fuel for delivery vehicles, and some retail stores have done so as well. Seven & i Holdings, a large retail chain operator, has built diesel fuel storage facilities to supply the vehicles used for making product deliveries to stores. The stockpile is sufficient to allow the company to deliver supplies to all 5,100 of its convenience stores and supermarkets nationwide, for a period of ten days. Thus, the diesel stockpile helps to ensure a supply of products to all of its stores in times of emergency.

21.9% of respondents said that they are diversifying delivery routes by cooperating with other companies in joint delivery schemes. Another 20.5% have diversified the number of contracted distribution companies they use, while 16.4% have taken steps to use alternative forms of transportation, such as railway or sea transport. Among the companies that have set up joint delivery systems, many have set up alliances of several companies, based on the idea that a group of firms will find it easier to find alternate transport capacity in times of emergency than a single company could accomplish, all by itself.

The attitudes that companies take towards risk have a major impact on what steps they take to respond. Among those companies that felt they had given adequate consideration to risk management prior to the quake, a large percentage had introduced proactive measures to diversify and disperse their distribution centres, or formulated plans to transfer distribution activities to other centres if one centre was unable to operate. A large percentage also had backup measures in place for their information systems, or had adopted earthquake-resistant designs for their facilities. Even though these measures may require significant investment costs, they improve the companies’ ability to respond to incidents such as the earthquake.

Among those companies which replied that they had given some thought to risk management both prior to and after the quake, or that they had considered risk factors prior to the quake, but after the quake they felt that it was necessary to give such matters even greater consideration, a large percentage indicate that they have now taken steps to discuss risk management with their logistics contractors, and confirm that response measures have been taken, or held meetings to discuss their response measures in the case of natural disasters or other risks. While it is certainly important to cooperate with logistics contractors, the perception still appears to be that someone else (i.e. the distribution company or contractor) is responsible for dealing with risk. There seems to be little recognition of the need to invest money to establish risk management systems. On the other hand, a large percentage do appreciate the need for backup information systems; a majority said that they have taken steps to improve these systems.
6. CONCLUSION

The Great East Japan Earthquake and its aftermath clearly exposed the weakness of existing logistics systems in Japan. Following the disaster, there has been a major change in the standards by which Japanese companies evaluate logistics systems. Prior to the quake, a majority of companies placed priority on management (cost) efficiency. After the quake, companies have begun to consider logistics from a more holistic standpoint, trying to develop ideal systems after considering their risk management capabilities and responsiveness as well as cost factors.

In their procurement activities, a majority of companies have taken steps to diversify their suppliers, both for items procured domestically and those items procured from overseas. Companies are also adjusting their production systems, designing plants to be more earthquake-resistant, dispersing production or building new capacity so that production can be shifted to alternate plants when necessary.

In their distribution activities, companies have begun to communicate more closely with logistics contractors to confirm risk-responsiveness and developing better backup systems for their distribution information systems. In addition, some are diversifying distribution centers or identifying alternative facilities to use if one distribution center is inoperable. However, most of these efforts have been taken individually, by each separate company.

It is necessary for companies to establish logistics systems which encompass their entire supply chain, so that all related companies can work together to address problems in case of a natural disaster or other disruption. It is also important to set up cooperative structures across industries, so that in cases where a large percentage of distribution facilities and transport equipment are damaged, companies can cooperate to make the most efficient use of those facilities still in operation. This form of cross-company and cross-industry cooperation is the next step that needs to be taken in efforts to deal with risk, and to better respond to future natural disasters.

7. REFERENCES


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THE IMPACT OF LOGISTICS SECURITY CONDITIONS ON THE LOGISTICAL EFFICIENCY OF THE PRODUCT

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Abstract

One of the most important purposes of each logistics system functioning is to define the desired security state. It should be noted that the various elements that refer to the security of the logistics system are related to a number of both external and internal conditions of the company. There is also a number of security areas dependent and independent from the company. On this basis, one can make a statement that the product itself, having specified characteristics and properties can affect the security of the logistics system. The article is an attempt to identify and describe the impact of logistics security conditions on vulnerability of product design, and consequently on the logistical efficiency of the product.

Keywords: security, vulnerability, efficiency, product, logistics

1. INTRODUCTION

The challenges faced by manufacturing companies of the 21st century increasingly more often concentrate around the problems related to the flow of goods and information which in a natural way associates itself with logistics, defined as the process of efficient and cost-effective flow of goods and information from the point of their origin to the place of consumption. This forces enterprises to re-think their functional and global strategies, into such that would account for the primacy of logistics problems. This leads to the necessity of introducing new concepts and ideas, which include the concept of Total Logistics Management (TLM) formulated by the authors.

The concept of TLM should become a strategic declaration of the enterprise, with its foundation considering the complexity of problems and organizational challenges of the 21st century. One of the key elements of the TLM concept is the need to compose some part of the logistical conditioning into the product itself, which is dependent on multiple factors and elements. Another challenge of TLM is the problem of logistic security. The below article is an attempt to interconnect both fields and define the conditions of logistic security that are possible to be composed into an item within the concept of the logistical efficiency of the product.

2. THE CONCEPT OF LOGISTICAL EFFICIENCY OF THE PRODUCT IN THE CONTEXT OF TOTAL LOGISTIC MANAGEMENT

For many companies the vision of managing through logistics – TLM, is strongly dependent on the product itself and the information connected to it. Both the product and the information should be subject to successful and efficient flow. The concept of TLM itself is connected with a certain group of concepts that are usually placed before logistics, such as:

- the comprehensive implementation of the “7R” rule (right product, right quantity, right condition, right place, right time, right customer, right price) [9],
- cost rationalization in management of the entire supply chain [13],
 comprehensive managing of the product in the context of logistics – the concept of a logistically efficient product.

- Provision of logistics security,
- ensuring logistic security,
- accounting for goods identification and IT support for the flow of goods and information.

One of the elements mentioned above is connected with the idea of comprehensive product management in logistic context. Thus, the idea of a logistically efficient product arises.

The concept of logistical efficiency of the product is based on the notion that the features and characteristics of the product itself have a fundamental influence on logistic management in the enterprise. We may therefore attempt a general statement that the correct product assessment in terms of logistical efficiency should be the starting point for any actions related to shaping the functional or global strategy of the company based on logistics (whether conceptual or adaptive [2]). However, in order to be able to implement this rule in the economic life reality on should first define the basic criteria of the discussed concept, including any conditioning that might be crucial here from the logistic perspective.

Analysing every product of the market exchange, one may state that it has some features and characteristics. Features are defined as elements distinguishing or characterizing the objects in some way, as an ingredient that does not function autonomously and may be differentiated only by means of thought analysis. Characteristics are defined as whatever is typical of the given item (the dominant features) [3]. Both features and characteristics of the product can either be natural or acquired. From the logistics perspective, this notion is extremely important as it allows to use a particular chosen logistic strategy and thus, directly or indirectly, influence the product itself.

The analysis and assessment in terms of natural and added features that foster logistic processes, is bound with the concept of logistical design vulnerability. Every product may be viewed as a set of natural features and characteristics, some of which can be modified and other that cannot undergo any transformation process. All those features and characteristics which are purposely designed create the set of acquired properties. The logistical design vulnerability of the product [4],[12] (composed of the transport, storage and organizational aspects) diagnoses the scope of possible changes that can positively influence logistic management. The key question here would be whether the analysis of the logistic security issues would make it easier to extract a group of factors that can be considered in the logistically efficient product design.

3. SELECTED NOTIONS OF LOGISTIC SECURITY

The rapid technological development and increasing range of economic globalization, along with the disappearance of traditional boundaries, are some of the many factors causing an increase in security threats within logistics systems. The number of factors generating risk is constantly growing along with the development of civilization. Among these we might include: rising energy and transport costs, the unexpected bankruptcy of strategic logistics providers, difficulty in maintaining regular cash flow, the need to adapt to the new requirements (including eco-logistics) of the local and international law, shortage of skilled employees among the shippers performing the loading of the goods or those providing transport services and logistics, rising insurance, road and credit fees.

The optimistic thing is that when new types of threats appear people are able to combat them by creating new methods, or by improving the older ways to organize prevention. The logistic systems, which are vulnerable to all changes and threats, both close and remote ones, due to the global length and width of the supply chain, must adapt to new technological, technical and legal conditions both in on the national and international scale.

The safety status of every system unstable and thus it cannot be seen as an item that is granted to the economic system once and for all. In the real world there are constant threats, caused both by the forces of nature as well as unintentional and intentional effects of human activities. Therefore every logistic system must put effort to assure itself a stable security status and, as a link in the supply chain, should include the possibility to react quickly to all changes, both internal and external, including the possibility of cooperation with other entities within the scope of the security system. This statement is nothing new as in the middle of the previous century, the father of contemporary management Drucker while proposing the criteria of choosing and designing an organization stated that every enterprise should have an end stability to survive in
the time of confusion and the ability to adjust to new conditions [10]. The adopted strategy of logistic functioning should not be targeted only on implementing logistic processes and lowering costs but also should take into account the issues of contemporary threats along the whole supply chain.

Every action in logistics both in the planning and real phase is burdened with uncertainty that may be caused by the arising threat (threats) or disruption(s). By threats to logistic security we mean all actions (events, incidents) that disrupt the realization of logistic processes, the flow of goods and information (along with the logistics processes associated with them, such as the processes of transport, warehousing, packaging, order handling and inventory management). One also needs to note that logistic security is hugely influenced by the logistics management areas that are indirectly or directly connected with the above-mentioned processes: the infrastructure of logistics stream and logistic costs. These kinds of events may occur individually or jointly, creating a situation that is hazardous from the business perspective for the economic system and all participants of the supply chains. These threats may be directed inwards or outwards, and the measures taken to reduce them should go in the same direction. Threats can be destructive to the logistic system disrupting the flow of the goods and information. These disruptions can be divided based on [6]:

- the place where the threat occurs;
- subsystem (according to the phase or functional approach to logistics [8]);
- duration;
- physical properties;
- range.

The short description of disruptions according to the duration or range criteria may not be included here as it is difficult to distinguish particular categories within these issues that can be used in the concept of logistical efficiency of the product. The remaining threats should be presented so that they might be referred to in the following chapter. The disruptions depicted within the place criterion will mainly apply to: routes of all transport modes (i.e. road, rail, air, inland-waterway and marine); the modal points of the logistic network often called transport points [11] (e.g. a warehouse, independent container points, airports, marine ports, logistics centers; auxiliary devices facilitating service on roads and at transport points, management (i.e. lack of full identification of threat effects, overestimation of capabilities, inaccurate interpretation of results, lack of tools for optimization and simulation of activities, growing prices of energy and transport, sudden bankruptcy of logistic service providers).

The disruptions depicted under the criterion of the functional subsystem refer to: transport (e.g. a fire, an explosion, an accident of the transport means, washing off the deck, lack of possibility to move due to weather conditions, defective transport means, unadjusted internal transportation, change in regulations of the transport management, thefts, catastrophes), related to inventory storage and shaping (e.g. a warehouse, independent container points, airports, marine ports, logistics centers; auxiliary devices facilitating service on roads and at transport points, management (i.e. lack of full identification of threat effects, overestimation of capabilities, inaccurate interpretation of results, lack of tools for optimization and simulation of activities, growing prices of energy and transport, sudden bankruptcy of logistic service providers). The disruptions depicted within the subsystem that accounts for the phase division of logistics are related to supply (e.g. lack of timeliness, bad quality, price or quantity, bad assortment, bribery, corruption, lack of possibility to obtain components for manufacturing, information system corruption, lack of buffer stock), production (e.g. inefficient manufacturing system, damage, losses, thefts of resources, availability of professional staff, production interruptions, technical failures, floods, fires, disasters), distribution (e.g. new products, new producers, thefts, economic crisis, neglecting customer relationship management, neglecting flow of goods management within the supply chain).

The disruptions classification that considers the materiality criterion is divided into: material ones (e.g. transport-related) information-based ones (e.g. damage of information system, damage of automated identification system), energy-related ones (e.g. concerning gas or fuel), assets-related (e.g. financial crisis);
Disruptions and threats have a direct influence on logistic security. However to be able to describe this notion, one needs to predefine what characterizes the safety of actions in logistic networks and channels. By definition, it can be said that it is a state that gives the feeling of certainty and a guarantee for:

- the flow of material goods and services;
- the flow of information for planning and management of logistics processes;
- protection and survival during dangerous situations (threats);
- adaption to new conditions (flexibility in unplanned situations).

The security level of logistics processes is dependent on the condition of the hazards of cooperating participants in the channels and networks at local and global levels.

The security of a logistics system is associated with:

- preparation and resistance level of the system to combat emergency situations (the majority of the attention is concentrated on recognition, monitoring, analysing data and correct decision-making within the scope of logistic operation along the entire supply chain);
- the quality of the created and functioning security system - understood as a set of forces and means of ensuring a security status acceptable by the participants of the international logistics network.

A certain degree of safety of international logistics can be achieved in various ways - not only by providing a predetermined efficiency of direct countermeasures towards occurred events. The people managing the company have the opportunity to shape the security level of international logistics services through thier management, which can be defined as a set of coordinated actions taken at the time of the emergence of threats (interference), aimed at the logistical resources of all members of the supply chain, with a view to achieve the objective, which may be the security of supply, reduce risks, to realize the conditions set by the owner of the cargo and the protection of market position and brand. Controllable values in this case are the parameters characterizing the factors affecting the level of security of the system, which is associated with¹:

- prevention of possible threats to the security processes implemented within the framework of international logistics.
- preparation of the logistics systems for the event of activation of these risks;
- resources countering these threats;
- removal of the consequences of the event.

Referring the presented notions to the logistic efficiency of the product it can be noticed that in fact the biggest influence on the product itself should be the prevention of possible threats to the security of the international logistics which includes:

- formulation of security policies by all members of supply chain;
- risk assessment [7][8] during the implementation of processes in the supply chain;
- developing a plan for managing and reducing the identified threats;
- detection, identification, recording and control the possible risks;
- foreseeing the possibility of crisis (e.g. with the use of data warehouses or computerized systems);
- examination of the acceptance level of risks in the supply chain among its members;
- determination of the type and scope of activities to prevent risks in the area such as road transport, warehousing, distribution, logistics costs – increased fuel costs;
- providing training to the people involved in logistics on both micro-level (individual economic system) and macro-level, with particular attention to:
  - the institutionalization of logistic relations
  - standardization of logistics processes,
  - standardization of processes (e.g. according to GS1)
  - increasing the requirements of the economic system transparency in business and logistics contacts,
  - tightening the criteria for risk-taking and the professionalization of activities within the supply chain

- need to broaden international cooperation of science and industry in the field of improvement of logistics processes,
- reconstruction of destroyed ecosystems and wider use of renewable energy sources,
- trust management, risk and security in logistics operations

The tools that help to manage the security of logistic systems at the micro and macro scale are the solutions that arise from the norms provided by national and international organizations as well as from various technical and technological aspects.

As for the normalization, it should be noted that in most cases it relates to the establishment of standards that systemically solve issues such as risk management in a supply chain (ISO 28000 2007), or ensure the continuity of the action (BS 25999:2007).

The group of technical and technological solutions includes among others: traceability (comprehensive traceability or origin - identification of the batch of the product, raw materials used for its manufacture, followed by individual identification of each product comprising the batch during production and/or distribution to the direct consumer), GS1 standard (bar codes and electronic product codes), Business Intelligence - BI (business intelligence) or the monitoring network.

4 THE IMPACT OF LOGISTIC SECURITY ON THE LOGISTIC EFFICIENCY OF THE PRODUCT

The above-presented logistics and security issues should be the basis of the considerations related to the design of the product itself as seen in the light of hereby discussed issues. The logistical efficiency of the product should allow for incorporation of certain solutions in the product itself to make it possible to provide more efficient and effective management across the entire supply chain. The presented overview of selected topics on logistics management clearly shows that there is a group of logistic security issues, which cannot be included in the logistical efficiency of the product. However, to attempt a discussion as to which safety features can be included in the product, one needs first to look closer at the issues that might possibly generate threats to logistics and analyse their impact on the product itself.

The division of disruptions presented in the article allows us to notice, that the factors categorized within the groups associated with the place, subsystem and physical attributes should have an impact on the concept of logistical efficiency of the product. The question of where disturbances occur, i.e. all modes of transport routes, modal points, auxiliary equipment to facilitate road maintenance and transport points, is in fact related to the concepts of transport, storage and organization vulnerability. The combination of the three together creates the logistic vulnerability of the product, which in turn is a key element of the logistics efficiency of the product. The same applies to the interference generated by the subsystems in terms of the functional and phase approach. The same might be said, to an even greater degree, of disruptions associated with physical properties, where the division to material and information-related interference, allows to decide which of the basic vulnerability analyses might include particular disturbances from this group. In the context of logistics system security, the level of preparedness and resilience of the system to the prevention of emergency situations, as well as the quality of the functioning security solutions, is inextricably linked to the organizational vulnerability of the product. Another, separate matter would be to investigate which of the elements associated with the preparation, resistance and quality of such a system can be integrated into the widely understood product, or, more precisely, into the its organizational vulnerability aspect. In case of both preventive measures and tools that assist safety management, one may see that, as regards the latter, that the impact of particular standards widely associated with logistics security, usually applies to the organizational sphere of company activity, forgetting the product itself. In most cases, no one analyses the possible changes in the product just adapt it to some specific standard unless this standard is enforced by law. The situation is different with technical and technological solutions. The implementation of identification systems based on the GS1 standard barcode or RFID or comprehensive Tracing, often forces the producers to incorporate specific sets of characters either directly into the product or its packaging, thus allowing to identify individual elements in each dimension. The described preventive actions range shows that the available range of processes affects product modification only indirectly. That so happens because they are mostly related only to the way the system is organized or managed, i.e. to its organizational vulnerability.
5 SUMMARY

The concept of logistic efficiency of the product implies the possibility of incorporating the optimum number of features and characteristics that would facilitate the flow of this product along with related information. To be able to discuss the issue further, one needs to distinguish the design vulnerability of the product, which consists of transportability, storage and organization, and describe the circumstances that may impact all of these vulnerabilities. The sphere of logistics security is one of the groups of conditions described here, which similarly to the customer service subsystem is mainly related to organization and management of logistic system. Organizational vulnerability clearly provides framework to the debated issue, at the same time affecting the logistical efficiency of the product.

The further scientific research intended by the authors will involve the identification of these factors of organizational susceptibility (including logistics security), which may already be intentionally designed at the stage of product design, thus increasing the subsequent efficiency of the entire logistic chain. Moreover, the above presentation of logistic security issues and logistical efficiency of the product allows the reader to notice that specific analytical tools allowing to diagnose the scale of threats and uncertainties of logistic operations in terms of security and the product itself, are yet missing; this matter will also become a focus of the further conducted research.

6. REFERENCES


SAFETY OF LOGISTICS SYSTEMS AS AN ELEMENT OF THE TOTAL LOGISTICS MANAGEMENT CONCEPT

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Abstract

One of the most important purposes of the functioning of each logistics system is to define the desired state of security and safety. It should be noted that the various elements relating to the security and safety of the logistics system are related to a number of both external and internal conditions of the company. There are also a number of security and safety areas dependent and independent from the company. On this basis, it can use that same product, having specified characteristics and properties can affect the security and safety of the logistics system. The article is an attempt to identify and describe the impact of logistics security conditions on vulnerability of product design, and consequently and in a wider range on the logistical efficiency of the product.

Keywords: security, safety, vulnerable, efficiency, product, logistics

1. INTRODUCTION

Manufacturing companies wishing to compete in the global market, face a number of challenges. Most of these are associated with the continuous rationalization of many functional areas of business, directly or indirectly related to production management. Much as in the 1950s or 60s the challenge for these companies was to rationalize production in its broad meaning, by the implementation of mass production principles, the 1980s and 1990s would in turn show the tendency to strengthen the role of quality management. The implementation of Total Quality Management main concepts, related to full customer satisfaction, led to a situation where, for many reasons, it is increasingly more difficult to find new quality features that constitute success factors for an organization, in accordance with the Kano model [1], [2]. Hence, product quality has been set on some stable level and is gradually dispensed to customers, aiming now only to ensure that the organization provides only a certain specific level of satisfaction.

The challenges of the 21st century manufacturing companies are increasingly more often concentrated on the issues related to the goods and information flow, which relate to the concept of logistics in a natural way. Logistics, defined as a process of efficient and economically effective flow of goods and information from the place of origin to the place of consumption, imposes the need to re-orientate their functional and global strategies onto such that in their assumptions have to account for the primacy of the logistics-related problems. This leads to the necessity to introduce new concepts and ideas, which may include the Total Logistics Management concept, formulated by the authors.

The very TLM concept should become a strategic declaration of a company, addressing the complexity of problems and challenges the organizations face in the 21st century.

Hence, the below article broadly describes TLM in the context of one of many 21st century logistics challenges, which is logistic security, that occurs across the entire TLM concept.

2. THE CONCEPT OF TOTAL LOGISTICS MANAGEMENT

As presented in the introduction, the idea of Total Logistics Management comes from the assumption that the 21st century is the time for enterprises oriented towards the flow of goods and information. This is the way companies should build their strategies both functional and global – based on logistics.
This matter, however, may be disputable to some, due to the fact that in many cases the magnitude of problems associated with production management, market competition, sales etc. is far more complex than solely logistics as such. Moreover, in many cases logistics becomes an area that is either secreted or outsourced, which generates a question whether it makes sense to include logistics-related problems into the strategic activity of companies. However, observing numerous examples of enterprises functioning on the global market (e.g. Ikea), we may see that they still decide to choose logistics as the strategic functioning factor on the market.

When attempting to define Total Logistics Management, it is impossible not to mention certain aspects included in it. Firstly, basing on the concept of Total Quality Management, one might define TLM as an approach to organization management, where every aspect of its activity is realized through the inclusion of the pro-logistics approach. Similarly as in TQM, TLM should also have its assumptions and principles, some of which may overlap with TQM.

As far as the principles are concerned, involvement of each employee in the company, activeness based on long-term deadlines or the optimization of the processes seem consistent for both concepts. This is because the mentioned activities are related the effectiveness and efficiency of management in every manufacturing enterprise. However, in the case of TQM, many of them are congruent with the principles formulated by the ISO quality management standard [3] and at least some part of them is universal enough to be applicable to both concepts. Hence, when we analyse the eight basic principles of quality management:

- putting customer first,
- leadership,
- employees’ involvement,
- process approach,
- system approach to management,
- continuous improvement,
- fact-based decision-making,
- mutually beneficial relationships with suppliers,

it becomes apparent that some of them are associated with management effectiveness (putting the customer first, leadership, employees involvement, continuous improvement, fact-based decision-making), while the second part applies to the system-based and process approach to organizations (e.g. the system approach to management, the process approach, continuous improvement or mutually beneficial relationships with suppliers). At this point a question arises, as to what elements need to be included in the TLM concept to distinctly emphasize the logistics management-related problems.

From the perspective of modern logistics, the most important challenges faced by this area of company management, that also become the TLM mission are:

- comprehensive implementation of the “7R” rule (right product, right quantity, right condition, right place, right time, right customer, right price) [11],
- cost rationalization in management of the entire supply chain,
- comprehensive product management in the logistics context – the concept of a logistically efficient product [4] [5],
- ensuring logistic security,
- accounting for goods identification and IT support for the flow of goods and information.

The combination of the above-presented elements with the basic principles of rational management formulated by the TQM concept, reveals the comprehensive idea of Total Logistics Management. The above-presented key logistic elements, among themselves, should have their structure and gradation. Both should stem from the specific conditions of enterprise functioning, hence any preliminary positioning of the issues in question might be somewhat difficult. For that reason, in this part of the paper, the authors will attempt to characterize the problem of logistic security in the context of the TLM concept.
Table 1 – Comparison between TQM and TLM

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</table>

3. SECURITY IN LOGISTICS

The security status of any system is not stable, and so it is not the good that the economic system was provided with once and for all. In real world, constant hazards occur, whether coming from the forces of nature or the unintended and intended effects of human activity. Therefore, every logistics system needs to strive to ensure a stable security status for itself. Each logistic economic system, being a link in a supply chain, should develop, among its activities, the ability to react promptly to any changes in its internal and external surroundings, including the possibility of cooperation within the confines of a security system, with other entities. This idea is nothing new, as already halfway through the last century, the father of contemporary management, Drucker, when putting forward the criteria for the selection and design of organizations stated that every company should possess the durability to survive any period of confusion and the ability to adapt to new conditions [12]. The adapted strategy of logistic functioning should not be focused solely on the realization of logistics processes and cost reduction, but it should also include the problem of contemporary hazards along the entire supply chain.

All actions in logistics, both in planning and real areas are burdened with some degree of uncertainty, which may be incurred by the danger (threat) or interference that appears. Security threats in logistics are all actions (phenomena, events) that disrupt the implementation of the logistics processes, the flow of goods and information (along with the logistics processes associated with them, such as the processes of transport, warehousing, packaging, order handling and inventory management). One also needs to note that logistic security is hugely influenced by the logistics management areas that are indirectly or directly connected with the above-mentioned processes: the infrastructure of logistics stream and logistics costs. These kinds of events may occur individually or jointly, creating a situation that is hazardous from the business perspective for the economic system and all participants of the supply chains. These threats may be directed inwards or outwards, and the measures taken to reduce them should go in the same direction.

Threats to logistics security may be divided into five groups. The first group includes natural disasters and events evoked by civilization-related causes, i.e. catastrophes, failures and other events caused by human activity or negligence. This group of threats includes, inter alia: fires and floods, strong winds and hurricanes, thefts, epidemics of human, plant and animal diseases, chemical and radioactive contamination, mining, construction and road disasters, grid failures. The second group includes events that threat the constitutional order of the nation(s); terrorism, road blockades, illegal demonstrations, ethnic conflicts, mass migration. The third group may include mechanisms that aim to destroy or distort information that is sent, transferred or stored for the needs of logistics. All disruptions in information flow cause difficulties in efficient and effective logistics management along the entire supply chain. The fourth group includes the threats that stem from the consequences of a financial crisis, which in fact affects everyone, including...
logistics processes and systems. Even an economy with great growth rates does not secure us from the crisis, and in fact the anti-crises instruments have not yet been fully developed. The fifth group includes threats related to the enterprise business (e.g. rapidly decreasing prices, the lack of quality adjustment to the preferences of the customer, mass departure of educated staff in search of better employment conditions, the enterprise not being able to follow the global trends, imported goods displace its production, corruption, bribery, stocking the hostility towards foreign companies, purposefully falsified data published by the rating companies, business intelligence, data banks, loss of credibility, insufficient activeness of employees caused by dissatisfaction and frustration). [6]

The mentioned threats may have a destructive effect on the logistic system, disturbing the flow of goods and information. These disruptions may be classified by the following [7]:

- the place where the threat occurs;
- subsystem (according to the phase or functional approach to logistics [8]);
- duration;
- physical properties;
- range.

The disruptions depicted within the place criterion will mainly apply to: routes of all transport modes (i.e. road, rail, air, inland-waterway and marine); the modal points (under the name of modal (most probable) points of logistic network we understand all places of stopovers for the goods, i.e. warehouses transport points and nodes, factories, distribution networks [13]) of the logistic network often called transport points (e.g. a warehouse, independent container points, airports, marine ports, logistics centers); auxiliary devices facilitating service on roads and at transport points, management (i.e. lack of full identification of danger effects, overestimation of capabilities, inaccurate interpretation of results, lack of tools for optimization and simulation of activities, growing prices of energy and transport, sudden bankruptcy of logistic service providers).

The disruptions depicted under the criterion of the functional subsystem refer to: transport (e.g. a fire, an explosion, an accident of the transport means, washing off the deck, lack of possibility to move due to weather conditions, defective transport means, unadjusted internal transportation, change in regulations of the transport management, thefts, catastrophes), related to inventory storage and shaping (e.g. thefts, losses due to oversized inventories, fires, floods, construction disasters, grid and IT network downtime, damage of the automatic identification system), packaging services (e.g. environment contamination, damage of the goods while transportation resulting from bad weather conditions), handling customer’s orders (e.g. shortage of inventories, incorrect order or invoice, late delivery, damaged goods delivered to the customer, lack of response to complaints and delays, fire, theft, destruction of goods). Information-related (e.g. loss of confidentiality, integrity and possibility to dispose, natural hazards such as fire, climate disruptions, electrostatic disruptions, passive and active attacks, random errors);

Disruptions depicted within the subsystem that accounts for the phase division of logistics concern aspects of: supply (e.g. lack of timeliness, bad quality, price or quantity, bad assortment, bribery, corruption, lack of possibility to obtain components for manufacturing, information system corruption, lack of buffer stock), production (e.g. inefficient manufacturing system, damage, losses, thefts of resources, availability of professional staff, production interruptions, technical failures, floods, fires, disasters), distribution (e.g. new products, new producers, thefts, economic crisis, neglecting customer relationship management, neglecting flow of goods management within the supply chain).

Disruptions, based on the duration criterion are divided into: short-term (intermittent); long-term, growing, recurrent).

The disruptions classification that considers the materiality criterion is divided into: material (e.g. transport-related) information-based (e.g. damage of information system, damage of automated identification system), energy-related (e.g. concerning gas or fuel), assets-related (e.g. financial crisis);

The last classification criterion for disruptions is based on the operational range: local, concerning the logistics of a given economic system, being a link of e.g. an euro-logistic channel, or vast (along the entire supply chain) [9].

Hence, the logistic security system should be adapted to potential threats and the required security level which needs to be ensured for it within logistic channels. Consequently, the number of measures necessary to
achieve the desired security level within the area of logistic activities, their organization and course of action (or processes, more specifically), after danger occurs (an event takes place) depends on its kind and scale, as well as on the prognoses of likelihood that other kind of danger might occur.

The security of operations within logistic networks and channels is the state that gives a sense of confidence and ensures the following:

- flow of goods and services; in consequence satisfaction of the material needs that the supply chain participants have, in accordance with the “7R” principle;
- protection and survival during dangerous situations (threats);
- adaptation to new conditions (flexibility in unplanned situations).

The security level of logistics processes is conditioned by the vulnerability of cooperating participants in channels and networks, on local and global scale.

The security of a logistic system is related to:

- The level of preparation and system resistance to counteract in extraordinary situations (the main attention is focused on the diagnosis, monitoring, analysing data and accurate decision-making in the area of logistics activities along the supply chain);
- the quality of the created and functioning security system - understood as a set of forces and means that ensure the security level acceptable for all participants of a logistic network;

Thus, a given specific level of logistic system security may be achieved in many ways, not only by ensuring particular effectiveness in direct counteraction against events that take place.

4. TOTAL LOGISTICS MANAGEMENT AND SECURITY OF LOGISTICS

The issue of logistics security should become one of more crucial elements of the TLM concept. However a question arises, in what way and place it should be set within the hereby discussed theory.

Analysing logistics security in the context of TLM, one needs to note that the problem may be discussed in two ways, depending on which of the two TLM areas we take into consideration. The first group of factors, related to the overall philosophy of efficient and effective company management is mostly related to the elements originating from TQM. Basically, the first group of factors (putting customer first, leadership, staff involvement, continuous improvement, fact-based decision-making) is directly linked with the organizational culture level, and so their influence on logistics security is significant, but still somehow limited. Hence, the second group of factors, this time concerning logistics itself, becomes the key element of the hereby-discussed theory. The security issue is inseparably linked with costs, information and IT systems, the concept of a logistically efficient product and the “7R” principle. The result is that, in many cases, the correlation of security with the mentioned conditioning of modern logistics should be precisely determined and defined.

At this point, it becomes necessary to place the issue of logistics security within the hierarchy and relating the problem to the remaining elements of TLM, related strictly to logistics. Concentrating on the first element of the TLM mission – the comprehensive implementation of the “7R” rules, which imposes on the company the necessity to focus its operations on the right product, in the right quantity and right condition would reach the right customer in the right time, with right price and to the right place. Here, one may clearly distinguish elements more and less prone to logistics security. It is difficult to ensure purely marketing-related factors, such as right product, right price, right customer or right place to be fully safe. In turn, the question of the right quantity, right condition or right time in which the product should reach the customer seems more vulnerable to safety issues. This stems from the fact that the presented problems are more in line with the procedural and systemic nature of logistics operations. It is much easier to extract real danger related to the lack of provisioning of the right quantity, condition or timing (by, for instance, the cause-result analysis, based on principles formed by Ishikawa [9] – 5M+5 – man, method, machine, material management + environment) and take the right corrective or preventive actions.

Some of the indicated factors are related to the area of IT support for the flows of goods and information, that include, for instance, the possibilities given by the goods identification systems (e.g. barcodes, electronic marking or traceability). This sphere of logistics safety will in many places support reduction of risks related e.g. to the right quantity of the goods supplied to the customer, at the same time being subject to danger related with broadly understood information and IT systems security.
The entire range of activities related to logistics security will be naturally associated with costs and, just as all the other remaining logistic actions, should be subject to continuous rationalization. Analogically as with quality-related costs [10], it will be optimized where the total costs of prevention and correction of the problems arising from deficiencies in security level will be equal.

In the end, the problem of safety of the product itself is yet to occur, together with a set of its features and characteristics, both natural and acquired, which in many cases will either be favourable to logistics security or they will generate problems, due to their nature. This fits in with the concept of the logistical efficiency of the product in which, within the confines of logistic design vulnerability, certain aspects of logistic security are taken into consideration, creating a vision of a final product.

5. SUMMARY

The concept of Total Logistic Management (TLM) clearly indicates that the issue of logistic security is becoming one of the key areas. The article depicts basic problems of logistic security as such, related to its hazards, but also outlines the basic relationships between particular areas of the TLM philosophy. However, it is worth to mention that the range of problem areas directly related with logistic security is extensive and requires further analysis, which currently lies within the research scope of the authors. Legal norms and regulations within the area of global logistics security apply to all supply chain participants and are local in their nature (e.g. Container Security Initiative - USA and Canada) as well as international ISO 28000 : 2007 Supply Chain Safety Management System).

The research interest of the authors also comprises placing selected logistics security elements in the product itself, which is related to research work on the logistical efficiency of the product, the concept of which has been presented in a separate publication.

The theoretical areas hereby presented in brief clearly indicate that the entire issue of building the idea for company management via logistics should be based on the concept of product building that includes its logistical efficiency and the crucial issue which is logistic management.

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MULTI-OBJECTIVE ASSIGNMENT STRATEGY FOR WAREHOUSES SERVED BY AUTOMATIC STORAGE AND RETRIEVAL SYSTEM

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Abstract
Storage assignment strategies play a crucial role to increase the warehouse efficiency and to reduce the inbound logistic costs. This paper presents a linear programming model to optimise the load assignment within an Automated Storage and Retrieval System (AS/RS) adopting a multi-objective perspective. Three different issues are considered: the time efficiency for the S/R operations; the overall energy consumption for the S/R activities; and the risk of the rack overturn and collapse during dangers like seismic events. The model is applied to a realistic case study to demonstrate its effectiveness and strengths.

Keywords: storage assignment, warehouse design, multi-objective optimization, AS/RS system.

1. INTRODUCTION
Warehousing activities to store/retrieve products from their locations are known as labour-intensive and high time-consuming issues [1]. Such activities often cause more than the 50% of the warehouse operational costs, while the adopted load assignment strategy has a direct impact on the overall efficiency level [2]. The so-called load assignment problem deals with the decision of how to store items in an existing warehouse meeting predefined logistic performance goals [3]. [4] faces such an issue from a time and cost perspective. The basic strategy is to store high rotation index products close to the pick-up & delivery (P&D) point to reduce the required time for the storage/retrieval (S/R) activities [6]. Furthermore, Automated Storage and Retrieval System (AS/RS) are widely used in modern distribution centres as they provide fast, accurate and efficient material handling [5]. [6] and [7] face the load assignment problem for such automated systems to minimise storage transportation distances and reducing the overall energy consumption and costs.

During dangers as the seismic events, the risk of the rack collapse generates a significant life-safety hazard with inestimable social and economic costs [8]. As a consequence, the storage assignment strategy needs to consider such a crucial issue. No analytic models are proposed to prevent the effect of the seismic events. This paper faces such an issue presenting a multi-objective integer linear programming (ILP) model for the unit-load assignment problem (ULAP). The aim of the model is to define the most effective product assignment to optimise the product S/R from a multi-objective perspective. The time efficiency and the energy consumption optimisation of S/R operations are the goals of the ILP model to define the optimal load assignment strategy. A further perspective is introduced, to include the rack stability issue. The model description is followed by its application to a realistic case study facing the load assignment for an automatic warehouse located in Italy. Finally, the solutions of the model lead to several load assignment alternatives that optimise both the time efficiency and the energy consumption of the S/R operations.

According to the introduced topic, the remainder of this paper is organised as follows: the next Section 2 reviews the recent literature and regulations in force about the assignment strategies and the stability issue for the unit-load storage systems. Section 3 introduces the reference problems, while Section 4 describes the ILP model formulation. Section 5 presents the case study goals and input. The multi-objective analysis outcomes are in Section 6. Finally, Section 7 concludes the present paper with a summary and suggestions for the future research.
2. LITERATURE REVIEW

The load assignment strategies lead to the efficient warehouse management through the minimisation of the travelled distance and the total cost for the S/R activities [2]. According to [9], inbound travel time to S/R products from the storage area is considered as a significant waste source. It generates costs without adding value to the products. The warehouse design and the product assignment directly influence the inbound travelled time. As a consequence, the efficiency of AS/RS is based on efficient storage location management [10].

The past and the recent literature widely face the ULAP introducing several load allocation strategies and methods [11,12]. Typical assignment strategies try to store items with high order frequencies close to the P/D point [13,14]. All the aforementioned studies face the ULAP from a time perspective. They look for the assignment strategy that leads to the minimum time for the S/R activities.

[15] face such an issue for AS/RS to define a cost-efficient storage system through the minimization of the inbound travelled time. Furthermore, the energy consumption for S/R activities influences the cost-efficiency of AS/RS warehouses and the previous literature faces such an issue in the study of the assignment strategies. [16] analyse how picking operations can be optimised when energy saving replaces the traditional time-based focus. [9] study the storage location assignment in AS/RS introducing an energy consumption mathematical model to improve the loading-unloading operation efficiency.

A parallel and more limited research path focuses on the structural analysis of the storage systems when a force field acts on them. The most of the contributions consider the forces effect on the racks, neglecting the role played by the stored items [8]. Furthermore, existing regulations define how to calculate the seismic action on a static structure supporting the design of anti-seismic racks, e.g. [17,18]. Laws actually in force include general recommendations about the load assignment problem, only. The current practice is far from adopting quantitative optimisation models. Furthermore, no contribution joins in the same approach logistic and structural goals and no suggestion for the storage assignment is provided.

To meet the introduced research lacks, the multi-objective ILP model presented in this paper faces the ULAP with the aim to minimise the average bay access time and the energy consumption, subject to the rack collapse prevention in the case a seismic event occurs.

3. PROBLEM STATEMENT

In the following the adopted assumptions and the problem statement are introduced before presenting the multi-objective ILP model for the ULAP.

3.1 Operation assumptions

The assumptions behind the ULAP model are listed below.

- The storage locations admit all the product loads. No geometric constraint is introduced
- The travel time and the energy consumption for the S/R operations is due to single-command cycles
- Each rack is supposed to be an infinite-stiff structure
- The seismic action acts on each rack, independently
- The so-called permanent load caused by the structure weight is omitted because it is equally distributed through the structure and it is out of the ULAP decision range

Furthermore, the legislations actually in force split the seismic action vector into three components, \( F_{s,x}, F_{s,y}, F_{s,z} \), as in Figure 1 [18]. In the following, the horizontal component \( F_{s,x} \), acting perpendicularly to the plan of the racks, is considered, only. During a seismic event, such a component gives the major contribution to the structure motion causing its overturn or the load fall onto the corridors.

3.2 Stability problem statement

According to the introduced assumptions, each rack is assumed to be exposed to two forces. Its global weight, \( F_w \), and the seismic action, \( F_s \). Both \( F_w \) and \( F_s \) are applied to the structure centre of mass, \( CM(\bar{x}_{CM}, \bar{y}_{CM}, \bar{z}_{CM}) \), as in Figure 2. They generate two moments acting in opposite directions. The former is called stabilising moment, \( M_s \), and opposes to the system motion, while the latter is called overturning
moment, \( M_o \), and forces the rack to collapse onto the aisles. The rack motion instant axis of rotation, \( CR \), is at the bottom edge of the structure.

![Figure 1 – Seismic vector components](image1)

![Figure 2 – Stability problem reference framework](image2)

The \( CM \) position depends on the load assignment. The height \( z^{CM} \) depends on the load distribution among levels. The higher the low levels are full, the lower \( z^{CM} \) is. Furthermore, considering an equal probability of finding \( CR \) either on the left or on the right edge of the rack, the horizontal distance between \( x^{CM} \) and \( CR \) is always half of the width of the storage structure, \( \omega/2 \). Finally, \( y^{CM} \) depends on the load distribution through the spans, and it does not affect the rotation moments. Equation (1) and Equation (2) present the analytic expressions for \( M_s \) and \( M_o \).

\[
M_s = m \cdot g \cdot x^{CM} \tag{1}
\]

\[
M_o = \alpha \cdot \lambda \cdot m \cdot g \cdot z^{CM} \tag{2}
\]

where \( m \) is the total mass of the loads stored in the rack, \( \alpha \) is the so-called seismic coefficient and \( \lambda \) is a further safety factor [21]. Both \( \alpha \) and \( \lambda \) are to compute to meet the seismic laws in force. The former coefficient depends on the soil stratigraphy, the warehouse location and the geometrical features of the structure, while the latter coefficient increases the seismic action intensity, for the sake of security. The following Equation (3) presents the analytic expression of \( \alpha \).

\[
\alpha = \frac{\alpha_s \cdot P \cdot S}{q \cdot g} \tag{3}
\]

where
- \( \alpha_s \) is the soil acceleration expected from a seismic event with a predefined recurrence interval, in m/s\(^2\)
- \( P \) is the probability that a seismic event with a soil acceleration of \( \alpha_s \) occurs during the overall warehouse operating life-time
- \( S \) is the subsoil topography coefficient
- \( q \) is the structure factor
- \( g \) is the gravitational acceleration, equal to 9.80665 m/s\(^2\)

The condition to guarantee the rack not to overturn is that \( M_o \) is lower than \( M_s \), as in Equation (4).

\[
m \cdot g \cdot (\alpha \cdot \lambda \cdot z^{CM} - x^{CM}) < 0 \tag{4}
\]

Such a condition defines the rack stability from a quantitative perspective and it is among the ILP model constraints introduced in the next Section 4 to face the ULAP including the warehouse stability issue.

### 3.3 Energy problem statement

The AS/RSs require energy to store/retrieve the unit-loads from/to warehouse locations. The energy consumption of such automatic systems, \( E \), influences the cost-efficiency of the storage system. The value of \( E \) is assumed as the sum of the energies provided for the horizontal and the vertical motions of the S/R machine.

The total work done by the S/R machine to store/retrieve a unit load in a single command cycle is as in the Equation (5)
\[(m_{ul} + 2 \cdot m_t) \cdot g \cdot E = F_a \cdot S_a + F_d \cdot S_d + F_r \cdot S_{tot} \quad (5)\]

where \(m_{ul}\) is the mass of the stored/retrieved unit-load and \(m_t\) is the mass of the S/R machine. Furthermore, \(F_a\) is the force acting along the acceleration distance \(S_a\), \(F_d\) is the force acting along the deceleration distance \(S_d\), while \(F_r\) is the dynamic friction during the full-length of the route \(S_{tot}\). The values of such \(F_a, S_a, F_d\) and \(S_d\) stem from the acceleration/deceleration and speed characteristics of the S/R machine, while \(F_r\) depends on the friction coefficients for the vertical and the horizontal motions. As a consequence, the minimisation of such a work leads to an increase in the S/R performances and cost-efficiency.

In the following Section 4, the ILP model is introduced with two objective functions that lead to a defined number of solutions. The time objective function \(\phi_1\) and the energy objective function \(\phi_2\) are introduced and the optimisation of both such functions leads to the optimal solutions of the model. Furthermore, the normalized normal constraint method is applied to generate the so-called Pareto frontier [19]. Each point of the frontier leads to a different load assignment through the bays of the warehouse and the analysis of such wave supports researchers and practitioners in the choice of the best warehouse configuration.

4. MODEL FORMULATION

The multi-objective ILP model to face the ULAP looks for the optimal warehouse configuration from a double perspective. Two objective functions, \(\phi_1\) and \(\phi_2\), are introduced to define the optimal load assignments. The \(\phi_1\) goal is the best load assignment to minimise the average single-command cycle time to store/retrieve the generic product, while the aim of \(\phi_2\) is to minimise the single-command cycle energy consumption of the AS/RS.

The model input deal with the product list, the inbound handling features, the warehouse structural parameters and the seismic parameters of the geographical location.

The following notations are introduced next to those in the previous Section 3.

Indices
- \(P\) number of product type, (index \(p\))
- \(R\) number of racks, (index \(r\))
- \(L\) number of levels per rack, (index \(l\))
- \(S\) number of spans per rack, (index \(s\))
- \(B\) number of bays per rack, level and span, (index \(b\))

Parameters
- \(q_p\) number of loads of the product type \(p\) to store, in unit-load
- \(m_p\) mass of product type \(p\), in kg
- \(m_t\) mass of the S/R machine, in kg
- \(f_p\) demand frequency of product type \(p\), in \%
- \(H\) height of each bay, in m
- \(h_p\) vertical height of product type \(p\) unit-load centre of mass, in m
- \(t_{bstr}\) single-command cycle time to store/retrieve a unit-load from/to location in rack \(r\), level \(l\), span \(s\), bay \(b\), in s
- \(E_{bstr}\) single-command cycle energy consumption to store/retrieve a unit-load from/to location in rack \(r\), level \(l\), span \(s\), bay \(b\), in J/kg
- \(\xi\) beam weight capacity, in kg
- \(\psi\) abutment weight capacity, in kg

\(R\) identical storage racks, coupled in parallel structures, are present. For each rack, the \(L\) levels and \(S\) spans cross defining the bays in which the unit-loads are stored. Consequently, each available position is univocally identified by its \((b, s, l, r)\) coordinates.

The multi-objective ILP model decisional variables assign products to the warehouse locations. Analytically,

\[A_{bstr}^p = \begin{cases} 1 & \text{if product type } p \text{ is assigned to } (b, s, l, r) \text{ location} \\ 0 & \text{otherwise} \end{cases} \quad \forall p, b, s, l, r \quad (6)\]

Equation (6) and Equation (7) present the model objective functions.
\[
\phi_1 = \sum_{p=1}^{P} \left( f_p \cdot \frac{1}{q_p} \cdot \sum_{r=1}^{R} \sum_{s=1}^{L} \sum_{b=1}^{B} A_{bst}^p \cdot t_{bst} \right) 
\] (7)

\[
\phi_2 = \sum_{p=1}^{P} \left( f_p \cdot \frac{1}{q_p} \cdot \sum_{r=1}^{R} \sum_{s=1}^{L} \sum_{b=1}^{B} A_{bst}^p \cdot (m_p + 2 \cdot m_r) \cdot E_{bst} \right) 
\] (8)

For each product type, \( p \), the time objective function in Equation (7) computes the average time to reach the locations storing a load of such a product. All the values are weighted by their correspondent frequencies, \( f_p \).

The energy objective function in Equation (8) stems from the Equation (5) and it is similar to Equation (7), i.e. for each product type, \( p \), \( \phi_2 \) computes the average energy consumption to reach the locations storing a load of such product. All the values are weighted by their correspondent frequencies, \( f_p \), as in the previous \( \phi_1 \).

In the following the proposed multi-objective ILP model formulation.

\[
\min(\phi_1, \phi_2) \] (9)

\[
\sum_{r=1}^{R} \sum_{s=1}^{L} \sum_{b=1}^{B} A_{bst}^p = q_p 
\] (10)

\[
\sum_{p=1}^{P} A_{bst}^p \leq 1 \quad \forall \, b, s, l, r 
\] (11)

\[
\sum_{l=2}^{L} \sum_{s=1}^{S} \sum_{b=1}^{B} \sum_{p=1}^{P} \left( A_{bst}^p + A_{bst}^{p+1} \right) \cdot m_p \cdot g \cdot \left( \alpha \cdot \lambda \cdot \left( (l-1) \cdot H + h_p \right) \right) < 0 
\] (12)

\[
\sum_{b=1}^{B} \sum_{p=1}^{P} A_{bst}^p \cdot m_p \leq \xi \quad \forall \, r, s, l = 2, \ldots, L 
\] (13)

\[
\sum_{l=2}^{L} \sum_{s=1}^{S} \sum_{b=1}^{B} \sum_{p=1}^{P} \left( \frac{A_{bst}^p \cdot m_p}{2} + \frac{A_{bst}^{p+1} \cdot m_p}{2} \right) \leq \psi \quad \forall \, r, s = 2, \ldots, S 
\] (14)

\[
A_{bst}^p \text{ binary} \quad \forall \, b, s, l, r, p 
\] (15)

Equation (9) minimises the introduced time-based and energy-based objective functions, while Equation (10) forces to allocate all the \( q_p \) unit-loads for each product type, \( p \). Equation (11) limits to one the load capacity of each warehouse storage location, while Equation (12) is from previous Equation (4) and forces the overturning moment to be lower than the stabilising moment. This constraint is for each couple of adjacent racks. Furthermore, Equations (13) and (14) set the maximum capacity of each beam and abutment to \( \xi \) and \( \psi \), respectively. Finally, Equation (15) gives consistence to the binary variables. The proposed model size is of \( P \cdot R \cdot L \cdot S \cdot B \) binary variables and \( P + R \cdot L \cdot S \cdot (B + 1) - R/2 \) constraints.

In the next Section 5 a full application of the proposed model is discussed considering a storage system for an automatic warehouse located in Italy. The input data are discussed before presenting and comparing the results and conclusions.

5. CASE STUDY

This section applies the proposed ILP model to a realistic case study. The unit-load storage area for an automatic warehouse located in Italy is focused to define effective allocation strategies.

The overall storage system dimensions are of about 12.3x55.2x23.5(h) m and the system capacity is of 4,104 unit-loads. 6 single-deep racks are present with 3 aisles. Each storage structure consists of two racks back-connected through proper steel connectors, called row-spacers in the material handling industry. The racks are supposed to be perfectly coupled and their behaviour is comparable to that of rigid structures. Table 1 further presents the features of the introduced storage area. Such parameters are among the input data of the model.

<table>
<thead>
<tr>
<th>Notation</th>
<th>( r )</th>
<th>( l )</th>
<th>( s )</th>
<th>( b )</th>
<th>( \omega )</th>
<th>( H )</th>
<th>( \xi )</th>
<th>( \psi )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>2</td>
<td>12</td>
<td>19</td>
<td>3</td>
<td>2.6 m</td>
<td>1.844 m</td>
<td>2,200 kg</td>
<td>22,000 kg</td>
</tr>
</tbody>
</table>

The product types are 145, while the number of the loads to store ranges from 10 to 100 per product, so that the overall warehouse filling rate is of about 81%. Furthermore, \( h_p \) is supposed to be the same for all the items and equal to 0.922 m.
In AS/RSs, cranes simultaneously travel along horizontal and vertical axes. The Chebyshev distance metric is adopted [20] to compute the single-command cycle time ($t_{bstr}$) and the energy consumption ($E_{bstr}$) to store/retrieve a unit-load from/to location in rack $r$, level $l$, span $s$, bay $b$, in s. Both the values of $t_{bstr}$ and the values of $E_{bstr}$ are among the inputs of the model.

Furthermore, the seismic parameters $\alpha$ and $\lambda$ are for an industrial warehouse located in Bologna, Italy (latitude 44.50° North, longitude 11.50° East). Particularly, the expected soil acceleration $a_s$ is 1.205 m/s$^2$ for a 475 years recurrence interval. The subsoil topography coefficient $S$ is equal to 15, while $P$ is 10%. Finally, the structure factor is $q = 2$ and the safety factor for the racks is $\lambda = 1.35$. Such parameters lead to $\alpha = 0.0921$.

The introduced data fully define the ILP model input to tackle the ULAP for the considered case study. 595,080 binary variables are introduced, while Equations (10) to (15) lead to 5,614 constraints. Both the model and the input data are coded in AMPL language and processed adopting Gurobi Optimizer© v.5.5 solver. An Intel® Core™ i7-3770 CPU @ 3.40GHz and 16.0GB RAM workstation is used. The branch-and-bound algorithm solving time is approximately of 43,200 seconds.

The following Section 6 shows the effects of the introduced multi-objective ILP model and its solutions to support researchers and practitioners in the choice of the best warehouse configuration.

### 6. RESULTS AND DISCUSSION

The introduced data fully define the input to the multi-objective ILP model to tackle the ULAP for the considered case study. Each multi-objective solution is identified by a set of decision variable values that make "quasi" optimal each objective function. Furthermore, each model solution describes a configuration of the warehouse.

At first, limiting the model to the sole time objective function, its optimal value is $\phi_1 = 57.13$ s, while $\phi_2 = 953,301.79$ J is the optimal value adopting the energy objective function, only. Such values identify the so-called anchor points [19], called $T$ and $E$ in the following (see in Figure 2). Their coordinates are $T (57.13;1,182,311.30)$ and $E (60.91;953,301.79)$.
Figure 3 graphs the obtained Pareto frontier, while its point coordinates are listed in Table 2. Furthermore, the following Figure 4 shows the effectiveness of each solution from a multi-objective perspective.

![Figure 4](image.png)

**Figure 4** – Time and energy consumption variances from $\phi_1$ and $\phi_2$ optimal values

For each solution of the ILP model, both the time efficiency and the energy consumption variances from the optimal values in $T$ and $E$ are in Figure 4. The optimal time-based solution in $T$ leads to a 24% increase of the energy consumption, while the time performance reduction in $E$ is about 6.61%. The higher the proximity of the solution to the $\phi_1$ optimal value, the higher the $\phi_2$ performance reduction is, and vice-versa. Nevertheless, the solution in Point 13 (see the red point in Figure 3) is an effective trade-off between the time and the energy consumption objectives, i.e. Figure 4 shows that both the time efficiency and the energy consumption for such a solution are close to their optimal values. Furthermore, the solutions from points $T$ to $E$ define the same number of assignment solutions that are good alternatives in a multi-objective perspective and the choice of the best warehouse configuration is left to the practitioners.

7. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

This paper focuses on the unit-load assignment problem (ULAP) for automatic warehouses located in seismic areas. A multi-objective integer linear programming (ILP) model to optimise the load assignment is presented. The model aims to minimise the average required time and energy consumption to store/retrieve the products from/to the storage locations. Furthermore, it includes the assessment of the rack stability to prevent their collapse and the load fall in the case of a seismic event. A case study is presented and the results show that the optimisation of both the time and the energy consumption objectives lead to different optimal assignment solutions. The multi-objective optimisation further introduces several optimal assignment alternatives to help practitioners in the choice of the best warehouse configuration.

Despite the conclusions drawn from the case study are not general and valid for all contexts, they appear promising suggesting to further investigate this topic to highlight general trends and effective rules-of-thumb to help practitioners to face the ULAP. Finally, extensions of the model to include further objective functions, e.g. the environmental impact and carbon dioxide emission, are among possible extensions of the present study.

8. REFERENCES


NFC APPLICATIONS IN THE TRACKING SYSTEMS

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Abstract

Radio Frequency Identification (RFID) and a Near Field Communication (NFC) is an automatic identification method, relying on storing and remotely retrieving data using devices different devices. An RFID tag and NFC devices is a small object that contains an antenna that enables it to receive and respond to radio-frequency. Basic requirements that these devices have to work in any conditions. In the working environment (closed or open air) there are always objects which can interact with radio frequency. This technical problem is to be considered when it comes to implementation of RFID or NFC devices knowing that materials can reflect, absorb or detune radio waves.

In our paper we describe a system where NFC is applied. Many economic and technological questions arise by the implementation and usage.

Keywords: RFID, NFC, logistics, tracking

1. INTRODUCTION

It is without doubt that introduction of RFId gives advantage to companies by helping them the integration in supply chains. However RFId – although widely used – need to be improved be-cause of one way communication. This is why Sony and Philips created the two way communication standard, the NFC in 2003. The requirement for NFC is similar to the RFId but be-cause of the possibilities of a two way communication it can be used in situations previously impossible.

2. POSSIBILITIES AND PROBLEMS

2.1 RFId technology

RFId technology is a technology for storing data appropriate for identification and describing attributes on an RFId tag that allows retrieving these data from far places via an RFId device attached to an antenna. The tag chip can be attached to products, unit load devices, animals etc. It is connected to an antenna which allows receiving and reflecting questions by radio frequency. Production of these devices is a very complex task. Low energy consumption is needed and the antenna has to meet various requirements (frequency, performance etc.). Communication between the reader and the tag is based on the theory of spreading radio waves. When the tag enters the electronic (or magnetic) field generated by the reader, it for-wards its unique identification or any other stored information. RFId tags are classified de-pending on their power source, among active (with own power source) and passive (with no own power source, so they are triggered by the field of the reader’s antenna). The reader can be attached to a computer, thus identification becomes integrated in the company system. [11]

2.2 NFC technology

The NFC standard creates a possibility for fast direct and simple communication within few centimeters distance for passive and active devices, cards, and smart phones. The communication requires an active chip on at least one side that can support energy to the passive chip through its antenna, awakening it. The passive chip emits the stored data which can be read by the active chip.

The capacity depends from the size of the data storage layer. The smallest tags can store 64 bytes but the currently available tags are able to store one kilobyte. The row chip needs preparation and treatment to...
function. The chips can be banded but not heavy duty. [10] The base chips can be placed in layered paper but special treatment is needed to function on placed it on metal. The interference caused by the metal can disturb the communication. More expensive chips can have UV protection needed for outdoor use.

2.3 Radio frequency communication range

Any device using radio frequency communication has a definite frequency for reliable message transmission. If the distance between sender and receiver increases exceeding a definite value, transmission fails. This is why it is a good idea to operate the radio communication system with a margin that does not coincide with the maximum range. It is required to do to achieve reliable performance, since the range changes from moment to moment. The exact range is affected by various factors, thus in simple terms there are four:

- the power in the RF wave transmitted,
- the sensitivity of the receiving equipment
- the environment in which the waves travel
- the presence of interference.

These are more or less obvious, but the relationship between the power and range is of high importance. Radio waves disperse in any direction after leaving the transmitting antenna (in case of non-directed antennas). Also the effect of environment on radio communication influences the frequency transmission. Electromagnetic radiation passing through the material may be reflected, detuned or absorbed to a certain extent, depending on the properties of the material and the type of radiation.

The operation frequency of NFC systems effects the operating range. According to the analysis of the physics of NFC communication the optimum frequency is 13,56 MHz this frequency determined on the basis of RFID “ISO/IEC 14443 A&B and JIS-X 6319-4” standard. [9]

This kind of analysis cannot be regarded as general since there are plenty of factors to be taken into account which result in different effects depending on application. Factors affected by choice of frequency include for instance: size of antenna, problems of power delivery to the tag, problems of communication of the tag back to the reader. [11]

The distance of communication is limited to few centimeters and so is the bandwidth of data transfer which is limited 424kbit/sec. However the stored data can be emitted within a second.

Even though it is slow compared the other standard it using minimum energy and there is no need for pairing the devices.

2.4 Environmental challenges

NFC devices have to work in any conditions. In the working environment (closed or open air) there are always objects which can interact with radio frequency. This technical problem is to be considered when it comes to implementation of NFC devices knowing that materials can reflect, absorb or detune radio waves.

Electromagnetic waves can be reflected off any conductive or non-conductive surface, such as metal, water or concrete. Reflection can result in an opposite effect, namely waves can be reflected in the environment of objects which would normally barrier radio waves or the waves result in an enhanced signal after reaching the same phase. The opposite can also occur, that is the waves cancel themselves which results in a no-read situation. The side effects can be reduced by using multiple antennas. Note that nulls are of more frequent occurrence than enhancements.

Attenuation of radio signals (due to absorption) depends on the properties of the material through which the electromagnetic waves travel. Absorption of energy is caused by the energy dissipating in the material that leads to resistance against the waves and is converted to heat [11].

3. NFC IN THE CORPORATE LOGISTICS

NFC and next to RFID systems provide solutions for corporate logistics problems.
Potential users of the new system indicated understand the core of business values of NFC implementations but they cannot clearly see how to proceed. They also recognized potential benefits of NFC systems which are provided for customers in improved productivity, asset management and accuracy.

They do not really understand how hardware and software components come together with NFC application, what changes are required to be introduced for enjoying benefits from the new technology and what changes are necessary to take on their own existing system. Another concern is who are the experts with expertise and previous project success that are suitable for providing enough help and advice to make the projects successful. [11]

The NFC system can be widely used similar to RFID technology, for example:

Receiving:
- better productivity,
- reduced labor costs,
- faster throughput at the receiving,
- no need of physical check of packaging slip,
- needs indicated for Cross-Docking system.

Storage:
- put away accuracy and efficiency,
- less bar codes required,
- better storage place utilization (random location system).

Pick and Pack:
- Picking accuracy (items),
- Productivity measurement,
- Time measurement,
- No need of manual scales.

Shipping:
- more accurate shipping process,
- automatic verification at the portal of outbound dock door,
- accounting all items leaving the premises.

Our papers describe a new possible field of used namely human resource monitoring. In many causes it is difficult to follow the movement of employers within parts of company. A few solutions already exist for this problem but the costs related the implementation and operation are high or it cannot be used in closed places. Our proposed solution to this problem will use the aforementioned NFC technology.

4. THE POSSIBILITY IMPLEMENTATION OF NFC TO TRACKING PRACTICE

In our paper we investigated the system of a security company.

Our aim is to locate the employer of the security company before arriving at the place of work. If the employer is not going to arrive to start the work on time the substitution can be arranged proactively.

4.1 Background Guard Service activities

The presence of the security guard at the facility is very important and without the facility cannot operate.

If the guard is late or cannot start the work at all the security company faces a high level of costs to be paid to the facility.
4.2 Current tracking practice

Current procedure of controlling the presence of guard can be done in two ways:

1. Directly: after showing up at the facility the guard calls the security company.
2. Indirectly: security system of the facility stores the data about the presence of the guard. This way the security company receives the data at the end of each month.

![Diagram of Daily report for duty](image)

**Figure 1** - Daily report for duty

This procedure is only able to recognize the presence of the guard thus making proactive measures impossible.

4.3 On-line tracking options

Because the aforementioned procedures it can be seen that the most important issue for the security company is to ensure the presence of the guard.

We propose online tracking of the guard. This way the security company receives information from the movement of the guard before he arrives at the workplace. This way they can react proactively to any problems.

**IT architecture**

- The main components of our hypothetical system model are as follows:
Databases
- Partner Data
- Data Model Task
- Data Guardian
- Contact details

Applications
- Strategic applications
- Planning applications
- Operational applications

Members
- Guards
- Replacement Guards
- Area Supervisors

Mobile Applications
- NFC
- GPRS

To the above listed connection system is shown in the following figure:

Figure 2 - IT architecture

The recommended applications developed using:
- At the strategic level: a proactive approach to labor supply, training and equipment,
- At the tactical level: managing of made plans, health and other criteria
- At the operational level: the implementation of the activity undertaken threatening can be detected in time.

5. POSSIBLE TRACKING SOLUTION
The guard receives a NFC device with GSM capability. After reaching designated places he is able to send a signal to the center.
The developed system components:
- Smartphone
- Reading program,
- NFC tags with location coordinates data
- GPRS network

In our model in NFC tags store the location coordinates. This way by using the NFC devices the guards send location data to the center.

We placed NFC tags a long route of the guard for example at home, bus stations, and the facility.

The path of the guards can be followed by this way automatically. The center can follow the movement of the guards, and so predicting the estimated time of arrival to work.

5.1 Pilot project
The guards and the substitonal guards are in online connection with the center.

![Diagram](image)

**Figure 3 - General tracking practices**

![Diagram](image)

**Figure 4 - Structure of pilot project**

![Diagram](image)

**Figure 5 - Example of NFC tags to accommodate**

The data was sent via GPRS network and decoded at the center.

![Diagram](image)

**Figure 6 - Example of reading NFC tags**

Reading was accomplished by the application NFC TagInfo available on the Android market the received data was sent manually via GPRS network to the central server at the university where it was decode.

If the company likes this idea, we need to code an android based application where data can be send automatically from the NFC device.

6. CONCLUSION
We can state that the widespread NFC technology penetrates various sectors of economy as well as commerce and tracking. Due to current investment and maintenance costs NFC application in tracking is not confined.

Our idea can be easily implemented at factories also where the tracking of the movement of the employees between the buildings is necessary.

REFERENCES
In the pilot project we used a smart phone which is NFC capable.

![Figure 5 - Example of NFC tags to accommodate](image)

The data was sent via GPRS network and decoded at the center.

![Figure 6 - Example of reading NFC tags](image)

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Our idea can be easily implemented at factories also where the tracking of the movement of the employees between the buildings is necessary.

REFERENCES


DEFINITION AND EXAMINATION OF WATERWAY CAPACITY

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Abstract

Hungary – situating in the centre of the continent – is one of the most loaded transit country in Europe. There are many TEN-T corridors crossing the country. The external cost coming from the heavy road transport is very high. On the other hand there are other eco-friendly transport modes available like railway or inland navigation. In the general approach navigation is an untrustworthy technology and has uncertain capacity.

The present study tries to change this opinion bringing new turn of mind. There are more way to define the waterway capacity. Because of the dynamic hydrological changes the cross-section has no stability, like road or railway cross-section. The paper shows these differences and deals with

- theoretical and planned capacity
- capacity factors
- flexibility analysis
- question of measure units
- time factor.

Keywords: external costs, waterway parameters, homogeneous/heterogeneous sections, capacity factors, static/dynamic capacity

1. INTRODUCTION

During the last years we could meet frequently the degrading and sentenced evaluations of the water transport in conjunction with the reports of the transport strategy. The correct designation of the place and future role of shipping between transport modes is essential in the terms of sustainable transport. Hungary – situated in the center of the continent – is the turntable of the Western Europe and Balkan destinations. As it is shown in Figure 1, six corridors of the TEN-T network are passing through the Carpathian Basin.

Transit traffic is significantly engages and burdens the areas of the country. The statistical data from the past few years are illustrated by Table 1.
Table 1 – Transport of goods in Hungary [2]

<table>
<thead>
<tr>
<th>Year</th>
<th>Thousands of tonnes</th>
<th>Millions of ton-kilometre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rail</td>
<td>road</td>
</tr>
<tr>
<td>2001</td>
<td>50 117</td>
<td>129 935</td>
</tr>
<tr>
<td>2002</td>
<td>50 370</td>
<td>217 099</td>
</tr>
<tr>
<td>2003</td>
<td>50 612</td>
<td>214 389</td>
</tr>
<tr>
<td>2004</td>
<td>51 726</td>
<td>213 339</td>
</tr>
<tr>
<td>2005</td>
<td>50 851</td>
<td>228 934</td>
</tr>
<tr>
<td>2006</td>
<td>54 706</td>
<td>250 800</td>
</tr>
<tr>
<td>2007</td>
<td>53 983</td>
<td>243 299</td>
</tr>
<tr>
<td>2008</td>
<td>51 543</td>
<td>258 380</td>
</tr>
<tr>
<td>2009</td>
<td>42 278</td>
<td>229 808</td>
</tr>
<tr>
<td>2010</td>
<td>45 794</td>
<td>199 848</td>
</tr>
<tr>
<td>2011</td>
<td>47 424</td>
<td>182 840</td>
</tr>
<tr>
<td>2012</td>
<td>46 177</td>
<td>165 514</td>
</tr>
</tbody>
</table>

The dominant share of the road traffic due to its commonly known externalities afflicts the environment, the society and also indirectly the economy, meanwhile our country has a significant waterway potential in the focus of the trans-European river network. Despite the fact that the occupancy of the Danube is evanescent, it is rather counted as an obstruction than as a solution during the transportation. As the transportation volumes are increasing, the specific environmental burden caused by certain modules has to be considered with growing responsibility. The basis of the sustainable transport planning can be only the externality-based perspective and the transport policy and industry development which are based on it. The external cost factors of the certain transport modes are shown in Figure 2.

![Figure 2 – The sum of external costs by transport modes [3]](image)

The prioritizing and even the usage of the inland waterway transport is still has a strong handicap because of the petrified approaches, such as comparison based on speed of advance instead of the large volumes of goods’ reaching speed, the mystification of environmental exposure under the modern technological equipment as well as the mentioning of the limited waterway occupancy.

Analyzing the latter thing is the main subject of this study.

2. CAPACITY IN TRAFFIC

In many times the capacity is confused with performance, so advisable to define it’s term, to localize its types and to separate its levels. [4]

2.1 Capacity and Types of Capacity

According to the general definition applied in management science, the capacity of equipment or an equipment group is interpreted as the maximal possibility of the equipment or the equipment group which can be achievable during a certain time unit in case of

- economically allowable maximum usage,
the best usage of the available area,
- the most modern technology and
- the application of the most developed organizing methods.

The mentioned factors can be interpreted in traffic, too. For example the economically allowable maximum usage of the track or the vehicle means the exposure limit until the track or the vehicle would not suffer such damages which can cause their premature deterioration and would not involve the unacceptable increasing of the maintenance and repair costs.

In traffic we can examine the capacity of the technical factors:
- vehicle or vehicle fleet,
- track (or track segment or junction) and
- transport facilities (station, repair plant)

Based on the above we can differentiate two main types of capacity, the capacity of
- vehicles and
- immobile equipment (tracks and supporting facilities).

The vehicles’ capacity is also called as transport capacity, and this means the maximum transport performance can be reached – in a determined track or network – by a vehicle or a vehicle fleet within a certain period.

The track capacity – or in other words: throughput – means the maximum amount of vehicles which can pass through in a determined cross-section of the track within a time unit. Capacity can be various in the different cross-sections, so the track’s standard (narrowest) cross-section must be determined.

The capacity of the supporting facilities can be interpreted depending on the feature provided by the facility. The capacity of the transport facilities (for example stations) or the traffic-provider equipment (for example loaders) means the maximum traffic volume can be proceed (can be served) by a certain facility or equipment within a given period. So, the capacity of the stations (airports, ports) can be expressed with the maximum received (manageable) amount of vehicles within a time unit, or with the equivalent quantity of passengers and goods.

2.2 Levels of Capacity

The transport efficiency which can be established within a certain period is mainly calculable as a theoretical value only, so it is usually called as theoretical maximum capacity. This value can be significantly differs from the predictable and reachable value calculated under real conditions.

That value what is less – but reasonably reachable – than its capacity, is called as predictable capacity or capacity-exploitation.

A further capacity-exploitation value could be the actually planned utilization of the capacity, which is the transport plan of a determined period.

The effective transport performance of a given period is obviously less than the capacity, so the effective transport performance can be considered as the determined usage of possibility (i.e. the capacity). Because of this it is called as capacity utilization (in its conjunction to capacity).

Based on the above facts we can create four levels for the efficiency of a given period, these levels are:
- capacity (the theoretical maximum capacity),
- capacity-exploitation (the predictable capacity)
- planned utilization of capacity and
- capacity utilization (the effective transport performance)

These separated levels and values of capacity can be interpreted the same way in its conjunction to track capacity.

In case of similar technical conditions (vehicles, tracks) the management-technological factors have determinative relevance in the degree of the capacity-exploitation and particularly in the degree of the effective capacity utilization.
3. THE CAPACITY OF SHIPPING

The capacity of each transport sub-sectors can be expressed in terms of unified theoretical bases described above, but it is must be expressed influenced by technological factors in accordance with the specificity of the particular transport method.

3.1 The Impact of Technical Aspects in Shipping

The elements listed at the general declaration can be interpreted in shipping as follows:

- transport capacity: the transport capacity of ships,
- track capacity: the throughput of the waterway,
- capacity of the supporting facilities: mainly the capacity of the ports and ship locks.

In the case of inland vessels the capacity of motor boats and freight carriers must be examined separately.

In waterways should be emphasised that the definition is relevant to waterways (and not to shipping lanes). Waterways have loading gauges which can be well-described with technical features, and these gauges can be isolated in the case of rivers and channels. [5]

In the case of supporting facilities transport/traffic and throughput-like values also can be occurred.

In fright shipping the ships’ capacity is basically determined by the carrying capacity (calibre) of vessels. At particular technologies in many cases we use freight carriers, which require motor boats for transmission.

The driving vehicles’ capacity can be specified with the maximum traction efficiency reachable on the given waterway during the examined period. This value can be converted to transport capacity using the proper utilization indicators (or in reserved order; the transport capacity can be converted to the required traction efficiency). Between the transport capacity of non-motorised ships and the converted transport capacity of motor boats the smaller value means the limiting factor.

The path capacity can be converted to transport capacity using the average utilization of transmittable vessels. Thus we can determine the transport capacity on behalf of ships and waterways, too. The efficiency of a transport method – and its enhancement – is limited as tight cross-section by the smaller value (namely the vessel, or the path). However path capacity usually has the primary role, the growth and increasing of the traffic in available waterway are limited by throughput capacity. The throughput capacity (and the corresponding transport capacity) also means the upper limit of the transport capacity, and we cannot reach efficiency higher than throughput capacity, regardless of the ship fleet’s increasing.

So efficiency can be increased by activating the open reserves of capacity, but not equally in certain technological factors. The magnitude and flexibility of these capacity elements (FCi) in a given examination period is illustrated on Figure 3.

![Figure 3 – Capacity and flexibility of the technical factors](image-url)
FCv : the flexibility of vehicles’ capacity, it can be increase without restraint, it is limited only by the market demands and the economic status of the shipping company, $F_{Cv} = \infty$ (capacity of the shipping facilities’ is the ultimate limit, so $C_{V\text{max}} = C_f$)

FCf : the increasing of the shipping facilities’ capacity is limited, it can be increase with more advanced technical solutions and organizational technique in case of serious traffic demand only, so its flexibility is minimal.

FCw : the throughput capacity of a waterway can be considered as a permanent value, it can be extended with long term major investments only, so the flexibility of its efficiency is zero, $F_{Cw} = 0$.

### 3.2 Capacity of the Waterways

In the case of inland navigation the path is usually linear, the throughput capacity of the network or the junction is not determining (not like in the case of public roads). The throughput capacity in a time period can be interpreted to the following:

- the entire waterway (river, channel)
- a transport destination
- a section of the waterway (just like the railways)
- a given cross-section (just like public roads).

In the case of the latter channels it can be used where the cross-section parameters can be considered constant. Cross-sections are strongly change on natural, unregulated water courses. A boat-length or formation-length unit can be considered as an independent section with its smallest limiting dimensions (depth, width and height).

In terms of throughput capacity we considered a part consists of constant cross-sections in a given time period as a single section. A transport destination consists of one or more sections:

- the single-stage transport route (with constant cross-sections) can be considered as homogeneous,
- and the multi-stage transport route (with changing cross-sections) as heterogeneous line.

However, the conditions of homogeneous and heterogeneous lines are also influenced by hydrological mechanisms, so their parameters are time-varying. The navigable section of a river consists of heterogeneous lines with space and time-varying characteristics because of its hydrology.

The levels interpreted in capacity theory also can be formulated to waterways, in first step to homogeneous lines:

- theoretical maximum capacity: with shuttling of the possible largest ships (a theoretical vessel) constructed in light of limiting geometrical waterway parameters (depth, width, bridge clearance, bend and angle radius) in the shortest, safely startable follow-up interval
- predictable capacity: the traffic's hydraulic permissible density of the largest convoys can be composed from standard-size ship units
- planned utilization of the capacity: the shuttling of the existing ship fleet with the frequency corrected by the previous interval's traffic

The capacity levels of each heterogeneous line are given by the smallest limiting factor from the values, which are calculated from the constitutive homogeneous sections.

### 3.3 The Expression of Waterway Capacity

At inland navigation in the first step we can examine the path's throughput capacity to homogeneous sections under the same hydrological conditions, which means such an interval when its parameters are constant. This approach can be made on the analogy of the public road's capacity.

In an indirect way at first we will take it stock that which measure units can express the expected value. The waterway capacity can be determined with:

- the number of the vessels can pass through during a certain time interval (choosing hour-unit): $[v/h]$. Practically on waterways we can use the transmittable quantity of ships with standard size (Europe II/B). To evaluate the efficiency the common view of treatme nt of watercrafts with different function and size
may be necessary the creation of an "vessel unit equivalent" – like in the case of public roads – by using proper balancing. The development of this method can be the object of a standalone study.

- the maximum throughput of the transport capacity expressed in deadweight: [dwt/h] or in volume: [m$^3$/h], which can be converted to quantity of goods: [ct/h] from deadweight or payload, taking account of the goods' loading coefficients.
- the maximum traffic capacity can be produced under a certain interval on the given section: [ctkm/h].

The first value can be calculated if we divide the useful time base with the follow-up interval of vessels.

$$C = \frac{T_b}{t_n}$$

where:
- $C$: waterway capacity
- $T_b$: useful time base
- $t_n$: follow-up interval

This is the simple formula of path capacity.

In the second case we involve the shuttled vessels' holding capacity into the formula. This formula gives the static capacity of the waterway.

$$C_s = \frac{T_b}{t_n}c_h$$

where:
- $C_s$: static capacity of the waterway
- $c_h$: holding capacity

We can get dynamic throughput capacity involving the standard travel speed of the section.

$$C_d = \frac{T_b}{t_n}c_hv_t$$

where:
- $C_d$: dynamic throughput capacity
- $v_t$: travel speed

The definitions above presumed the case of freight traffic, but they are also adaptable for passenger shipping – of course with using the different units of the transport. However the quantities in formulas are not fixed, they are dependents from many factors. In the case of homogeneous sections the useful time base itself is constant because of the definition of homogeneity ($T_b=\text{constant}$).

Technically the follow-up interval i.e. the shuttling frequency depends on:
- the following distance between ships and
- the travel speed of ships,

$$t_n = f(d_f; v_t)$$

however the economic considerations and the technological aspects are cannot be ignored, which are:
- market demands related to water transport on the section
- the purchase order volume, and therefore the dimensions of transport units and the applied transport method (self-propelled ships or pushed convoys)
- and the loading capacity which serves them.

From above the transport capacity of the ships applicable on the section is directly limited by the emergence of channel impact, namely the ship cross-section can be released without harmful effects in the existing channel cross-section under a given travel speed. Indirectly the affecting factors are the following:
- the depth and the width of the waterway
- the difference between the draught of empty ship and the maximum draught
- the safety clearance between the ship and the riverbed must be kept because of channel characteristics

$$c_h = f(d_w; b_w; t_u; d_s).$$
The travel speed comes from the technological standards of the ship fleet navigates on the section, but – as an inverse of the previous sentence – it cannot be enhanced limitless for reaching a greater transport capacity in order to avoid channel effect, so it depends on:

- basically the performance of the engine and the effective efficiency
- the applied propulsion method, propulsion efficiency
- the size and shape of the ship, so in total on the reachable Stillwater speed based on the facts above
- and the relative substance-speed, i.e. on the travelling direction on river water (upstream, downstream)

\[ v_1 = f(p_e; \eta_e; m_p; v_0; v_t) \]

As it could be seen there are internal correlations between the certain factors, so the modification of a value can also modify the value of another factor.

The throughput capacity of a heterogeneous line is given by the minimum of the throughput capacity calculable from the correlations above. In the case of a longer line (for example a line for a transportation) the question of temporality is also emerges, i.e. the capacity calculation of the line-building sections in separated time, in consideration of travel time.

Involving time factors also means hydrological relationship divergence by time and by sections. In one hand the hydrological changes causes differences in capacity factors stated for homogeneous sections. The other significant impact of hydrological processes is the fact that it determines the useable time base expressible on heterogeneous line by the intervals which are limiting or forbidding the shipping. These intervals are notoriously the flooding periods, icy days and the periods of extremely low water levels. Additionally the exploitable shipping time base can be reduced because of officially ordered waterway circuits (water construction works, excavations and water programmes). [6]

Involving hydrological processes and temporality we obtain to a higher mathematical level of expressing waterway capacity, where its multi-factorial examination is required.

Elaborating and building it is the further objective of my research.

4. CONCLUSION

A waterway is not consists of sections have constant loading gauges and (because of this) constant throughput capacity, contrary to e.g. a motorway. Complex nautical calculations must be performed in order to planning a concrete transport objective, partly with determining the limiting cross-sections and its parameters, and partly with the forecasting of water level conditions which can affect them.

The waterway categories themselves are already suggesting to the different capacities. However the effective quantification is a significantly more complex task.

The number and the ratio of unutilized (prohibited) days can be easily determined to waterways using statistical calculations. Determining the availability interval’s effective throughput capacity under changing water conditions is a more complex process.

We can obtain to the different capacity levels applied to technological factors of shipping with multiple steps using theoretically established structuralism. In my study I introduced a possible approach of this method, hoping that building on that foundation and using the proper methods, the quantification of waterway capacity will be achievable at least for an experimental section.

5. REFERENCES

Abstract

Improving the efficiency of the picking process is one of the most important areas in optimization of logistics processes. In warehousing, this involves the use of appropriate tools for computer-aided flow of information. The paper presents a model of a computer-aided tool that enables optimization of the picking process in the Kanban area of the studied magazine. Implementation of the presented tool resulted in reducing the picking process by 30 percent.

Keywords inventory, picking, computer-aided design tool, efficiency, lean, kanban, supermarket

1. INTRODUCTION

Computer-aided optimization of warehousing processes is currently one of the key areas for improvement in inventory management [1-4; 6; 10; 14]. Various tools offer functionalities that enable reducing task performance time, monitoring inventory levels, analysis of primary units of measure of process evaluation as well as different types of optimization [5-10; 14; 15]. Availability of such tools facilitates development of solutions most suitable for every individual organizational and technological environment.

The importance of taking account of the user’s needs coupled with in-depth understanding of how the processes for which the tool is developed are managed cannot be overestimated.

In the foregoing paper, a tool for optimization of a kanban area management is presented. The tool is supposed to allow dynamic adjustment of the size of the kanban area to the daily needs of the ordered materials. Two constraints to be taken into consideration while developing this kind of tools are the range of the area and ordering time. The main trigger for undertaking the project was the need for a flexible system that would enable monitoring and adjustment of the kanban area to the daily demand from the client [10 - 15].

2. A MODEL OF A COMPUTER-AIDED INVENTORY REPLENISHMENT SYSTEM

2.1 Operations in the kanban area of the studied warehouse

Examination of the picking process in the studied enterprise revealed that no detailed guidelines on how to operate such a system were available due to the fact that system updates were based on observation and hunches rather than on reliable calculations or statistical analyses. Therefore, procedures for inventory replenishment in the kanban area of the studied warehouse were prepared for the enterprise. The procedures are extensively discussed in “Project of picking inventory replenishment system” [7] where kanban principles were presented taking account the following two criteria:

- the number of picks of individual part numbers within a set time – made it possible to rank materials for allocation in the supermarket,
- the number of pallet UOMs of individual part numbers picked within a set time – made it possible to identify the number of pallet stocking locations that need to be allocated to materials qualified for supermarket allocation.
Further, the following principles were adopted in the design of the allocation of part number locations:

- part numbers with the highest number of picks should be allocated first and if possible, should be assigned locations in every other aisle starting with the aisle closest to the closest release point due to the fact that such materials should not be stored on racks in the same aisle as this might cause congestion in these storage areas,
- goods with the same part number to which more than one location has been assigned should occupy neighbouring locations or at least be placed within the same aisle,
- part numbers that are less frequently picked should be placed in the remaining empty locations,
- all of the part numbers qualified for the kanban supermarket should be located no farther than the fifteenth rack column (pedestrian traffic).

Figure 1 illustrates how goods are organized on racks.

![Diagram of goods organized on racks]

**Figure 1** – Illustrates how goods are organized on racks

*Source: Jahanžija I., Sekieta M., Szulc B., Project of picking inventory replenishment System, Conference Proceedings ICIL2012, Faculty of Mechanical Engineering and Naval Architecture Zagreb, Croatia 2012, pp. 247*
Due to the discovered need for a computer-aided inventory replenishment system, the objective of the project reported in this paper was to develop and implement an efficient, dynamic computer-aided inventory replenishment system in the kanban area.

The adopted principles need to be reflected in the database structure (2.2) and in the principles (2.3) that will be developed to manipulate the level of inventory in the warehouse.

2.2. Structure of data in warehousing processes

A predefined data structure was adopted in the development of the inventory replenishment system – Table 1. Microsoft Excel spreadsheet was used for data analysis (preferred version: Microsoft Excel 2007, due to the increased maximum number of rows and the function of duplicate value removal).

<table>
<thead>
<tr>
<th>Required data</th>
<th>Source</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of independent picks of each part number</td>
<td>Release report</td>
<td>Data available from Excel spreadsheets</td>
</tr>
<tr>
<td>Number of pallet UOMs of each part number</td>
<td>Release report, Stock status report</td>
<td>Data available from Excel spreadsheets; preferably, data source should be other than Stock status report, e.g. a goods catalogue with UOM characteristics – currently not available</td>
</tr>
<tr>
<td>Allocation of suppliers to rack rows</td>
<td>“Home racks” inventory</td>
<td>Data generated directly from the warehouse management system</td>
</tr>
<tr>
<td>Supplier/manufacturer code for each part number</td>
<td>Stock status report</td>
<td>Data available from Excel spreadsheets</td>
</tr>
<tr>
<td>High Value status of a part number</td>
<td>Stock status report</td>
<td>Data available from Excel spreadsheets; goods catalogue with unit of measure characteristics would be the preferred source of data – currently, not available</td>
</tr>
</tbody>
</table>

Tabela 1. Data fed into the inventory replenishment system with sources

Source: Jalmižna I., Sekieta M., Szulc B., Project of picking inventory replenishment System, Conference Proceedings ICIL2012, Faculty of Mechanical Engineering and Naval Architecture Zagreb, Croatia 2012, pp. 248

The data listed in Table 1 will enable inventory monitoring in the kanban area as well as its optimization and dynamic adjustment of its quantity and stocking location. The range of optimization will depend on the way the quantity and the volume of picks of each part number are determined. Consequently, in the 2.3. subsection, a model of a computer-based tool for the picking process is presented.

2.3. Procedure for the determination of the quantity and the volume of picks of each part number

“Supermarket layout spreadsheet” was developed in order to ensure proper optimization of replenishment operations. The quantity and the volume of picks of each part number in the spreadsheet will be determined on the basis of the procedure presented in Figure 2.

Individual pick of a part number is an indicator that was introduced for purposes of the developed tool. It is defined as reaching the stocking location and picking onto a pallet of one or a larger number of unit loads with the same part number. The parameter is a much more precise indicator of the workload involved in the movement of goods required for filling the orders than the frequently cited in the subject literature number of orders [1; 8] because a single request for a given item may refer each time to a different quantity which translates into the workload involved in carrying out the request. Unfortunately, “Atlas”, a warehouse management system, does not record from how many unique stocking locations a specific part number has been picked, i.e. the parameter which signifies the number of single independent picks. The value recorded by the system signifies from how many unique DUB codes a specific part number has been picked, which, in practice, is almost equivalent to the number of stocking locations except when the subsequent DUB of the same part number is in the same rack slot. In such a situation, two movements are recorded whereas,
actually, unit loads have been picked within one movement. Nevertheless, currently, the parameter of “from how many DUBs” yields the best approximation of the actual state out of all of the recorded parameters.

**Figure 2 – Procedure for determination of the quantity and the volume of picks of each part number**

*Source: Originally developed*

The inventory of part numbers sorted by the quantity and the volume of picks (marked as “Inventory B” in Figure 2) will be further used for calculating the number of pallet slots so that the stock in the warehouse could satisfy the estimated demand within set time. The computations are embedded in the so-called supermarket layout. The procedure for its preparation is illustrated in Figure 3.

Part of the prepared supermarket layout is presented in Figure 4 and explained in Table 2.
Figure 3 – Procedure for designing the supermarket layout

Source: Originally developed
Figure 4 – Part of a sample supermarket layout in Excel spreadsheet

Source: originally developed
Table 2. Explanation for Figure 4 (supermarket layout)

<table>
<thead>
<tr>
<th>Area</th>
<th>Column/cell</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E1 – E2</td>
<td>Enter date range of the data from release report</td>
</tr>
<tr>
<td></td>
<td>O1</td>
<td>Enter number of working days within the date range</td>
</tr>
<tr>
<td>1</td>
<td>R1</td>
<td>Enter the minimum number of picks per 24 hours to which one slot shall be assigned even if it follows from the computations that 0 slots should be assigned. This step ensures that part numbers picked frequently but in small quantity will not be overlooked in the supermarket</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>CLIENT part number</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>The total number of picks from unique DUB codes within the time between the end date and the start date = the number of individual picks</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>The total number of unit loads picked within the time between the end date and the start date</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>The total number of unit loads in a fully-loaded pallet unit of measure</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>Number of unique supplier codes assigned to part numbers; automatic highlighting of &gt;1 value</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>Supplier code</td>
</tr>
<tr>
<td>J</td>
<td></td>
<td>Position in the ranking; criterion: total number of unique DUB codes (column B)</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>Classification according to ABC analysis; computations in hidden columns G, H, I</td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>Number of picked pallet units of measure between the end date and the start date (column C/column D)</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>Average number of pallet UOMs picked every 24 hours (column M/number of working days)</td>
</tr>
</tbody>
</table>
| O    |              | Automatically assigned number of slots (comprising 3 pallet UOMs each) based on the average number of pallet UOMs picked every 24 hours (column N) and boundary values presented in Figure 5; Automatic visualization as colored circles:  
  • Black for values ≥ 5  
  • Red for values ≥ 3  
  • Yellow for values > 0  
  • Green for values = 0 |
| P-T  |              | Rack rows available for specific part numbers where they may be stored as a result of being labeled with a particular supplier code; based on the “home racks” inventory |

Source: originally developed

Supermarket layout spreadsheet automatically assigns a proper number of slots according to the quantity of picks following a user-modifiable key presented in Figure 5.
The user may define the level of safety stock according to the user’s needs however the value entered will hold for each part number. Therefore, a general key was set such that the first stocking slot is assigned to goods picked in the quantity of at least 1 pallet unit of measure per 24 hours (0.33 stocking slot per 24 hours). Subsequent ranges are calculated on the basis of the predetermined safety stock level in line with the rule that has it that the higher the level of the security stock, the earlier the subsequent stacking location is assigned. Larger security stock will safeguard against unforeseen increase in demand but it will require a larger supermarket.

Determining the level of safety stock is recommended due to significant fluctuations in daily number of individual picks of practically every part number released to the CLIENT from the main stocking section. The result of the XYZ analysis presented in Table 3 lend support to that claim.

<table>
<thead>
<tr>
<th>Group</th>
<th>Fluctuation range</th>
<th>Number of part numbers</th>
<th>Percentage share</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>below 20%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Y</td>
<td>≥20% i &lt;50%</td>
<td>47</td>
<td>3%</td>
</tr>
<tr>
<td>Z</td>
<td>≥50% i ≤100%</td>
<td>215</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td>above 100%</td>
<td>1612</td>
<td>86%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1874</td>
<td>100%</td>
</tr>
</tbody>
</table>

The person that updates the supermarket layout can set the boundary of part number classification in the inventory replenishment system (cell R1 in Figure 4). It may be a previously determined minimum number of picks per 24 hours to which at least one slot is to be assigned (goods with a lower number of picks will not be allocated to the supermarket). Alternatively, one can apply the results of the ABC analysis and reject goods from groups B and C.
3. SUMMARY

The model of a computer-based tool presented in the foregoing paper is an essential component enabling optimization of a traditional kanban area in the studied warehouse and dynamic adjustment of the number of stocking locations in the kanban area of the studied warehouse to the CLIENT needs.

The tests that the tool was subject to revealed that during the testing time the application of the tool resulted in a 30% increase of the studied kanban area efficiency.

The tests conducted prove that development of various computer-based tools to support processes in both SMEs as well as in big businesses is reasonable.

4. REFERENCES

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APPLICATION OF MATHEMATICAL MODEL FOR CONTAINER TRANSPORT FLOW OF GOODS: FROM FAR EAST TO SERBIA

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Studentski trg 16, 11000 Belgrade, Serbia

Abstract

This paper analyzes the supply chain network with primary focus on import of containers from Far East to Serbia through selected Mediterranean ports (Koper, Rijeka, Bar, Thessaloniki and Constanza). An optimization mathematical model, which minimize time and costs of container imports to Serbia, by using different liner shipping services on the sea and truck-rail-river inland transportation networks from selected ports is developed. By observing the bi-objective model for container flows from Far East through Mediterranean ports it was determined the most optimal route for container import to Serbia. Some customers require lowest freight rates while others need faster delivery.

Keywords: Container transport, Mathematical model, Bi-objective optimization

1. INTRODUCTION

The estimates of global seaborne trade increased by 4.3 per cent, with the total reaching over 9 billion tons in 2012 for the first time ever, but remains vulnerable to downside risks facing the world economy. For many decades, containerized trade has been the fastest-growing market segment accounting for over 16 per cent of global seaborne trade by volume in 2012 reaching 155 million TEUs and 1.58 billion tons. Containerized trade increased by 3.2 per cent in 2012, down from 13.1 per cent in 2010 and 7.1 per cent in 2011 [1].

The surge in container trade is mainly attributed to the increasing penetration of Asian products in developed European and American markets. In fact, container trade flows to and from Asia present the highest growth among the three main East-West trade routes (Asia-Europe, Transpacific and Transatlantic) which make 47 per cent of world maritime container trade flows. Specifically, during the period 1995-2011, container trade has increased by almost 5 times between Asia and Europe reaching about 20 million TEUs. Between Far East and Mediterranean 4.37 million TEUs was shipped using 31 different liner shipping services in 2012.

This paper analyzes the supply chain network with primary focus on import of containers from Far East (Port of Shanghai) to Serbia (city of Belgrade) through selected Mediterranean ports (Koper, Rijeka, Bar, Thessaloniki and Constanza), observing the six world's largest container operators (Maersk Line – MSK, Mediterranean Shipping Company – MSC, CMA CGM, Evergreen Line – EMC, China Ocean Shipping Company – COSCO and Hapag – Lloyd). Serbia is hinterland country and container import from Far East to Serbia needs to use different transport modes on inland to link shipping transport in the sea leg including railway, barge and truck. We considered only import containers in Serbia given the negligibly small exported quantities.

Although literature on freight transportation is large, containers assignment on intermodal networks is still an open issue. Studying literature data we conclude that a small number of researchers investigated at the same
time see and land legs together [2, 3, 4, 5, 6]. In most cases it is developed an optimization model which is based on the minimization for just one objective – transportation cost. Only few models integrated transit time as another objective [7, 8, 9], or included multiple objectives [3, 10, 11, 12]. Bi-objective models are applied to predict the most optimal route minimizing transportation cost and transit time.

In this study we developed bi-objective optimization model (BOOM), which minimize the time and cost of container import from Far East to Serbia. BOOM was programmed in MATLAB and simulations were performed on an Intel Core i7-3612 QM 2.1 GHz computer. Through the minimization of time and costs for container import flow from Far East through Mediterranean nodes it was determined the most optimal route for container import to Serbia which reached a number of 42 000 TEU in 2012. The BOOM first objective is transportation cost minimization, and the other is transit time minimization. This reflects the need of a diversified market as some customers prefer lowest freight rates while some others would rather pay more for a faster delivery.

The rest of this paper is organized as follows: Section 2 describes the problem which is considered in this work while the mathematical model is explained in Section 3. Section 4 reports and analyse the results of the mathematical model. Finally, Section 5 is devoted to conclusions and future developments.

2. PROBLEM DESCRIPTION

In this paper we consider an intermodal transportation chain which based on the import-way and composed by two legs. The first one represents maritime transfers from origin port – Shanghai port to gateway ports (Constanza, Thessaloniki, Bar, Rijeka, Koper). The second leg of the chain represents the inland component of the distribution, in which containers are routed from gateways to final destination – Belgrade, by road, rail or barge.

The network is composed by three categories of nodes: origin port (port of loading), gateway ports (ports of discharge) and destination (place of delivery), and two categories of links, maritime and inland. The detailed network is illustrated in Figure 1. Such elements of the network are described below.

2.1 Nodes

Each node type has its own characteristics:

Origin port – As one of the most important foreign trade partners in container imports from the Far East to Serbia is China with major port – port of Shanghai. It is the world's busiest trading port which handles a staggering 32 million containers a year, carrying 736 million tonnes of goods to far-flung places around the globe.

Gateway ports are connected with origin port, but only by incoming links. From origin port it is possible to reach a gateway port but the opposite is not allowed since here we are addressing only incoming flows. The main gateways for container import to Serbia are Constanza, Thessaloniki, Bar, Rijeka and Koper port.

Destination – Serbia is hinterland country with capital city – Belgrade. This region represents the largest percentage of Serbian imports in general. It is connected to the gateway ports with a direct link, representing the shortest path to reach it from that gateway, by road, rail, barge.

2.2 Links

There are two types of links, maritime and inland, each one with its own characteristics, as described below:

Maritime links are those between origin port and gateway ports. As for intercontinental links, there may be more than one link connecting an origin port to a gateway port, and each such link belongs to a different service with given travel time and frequency depends on different operators (Maersk Line, Mediterranean Shipping Company, CMA CGM, Evergreen Line, China Ocean Shipping Company and Hapag-Lloyd).

Inland links are those between gateway ports and place of delivery of containers – Belgrade. There are three available inland transportation modes which could be chosen including truck, railway and barge. Where there are available rail or barge linkages, line-haul may be done by rail or barge before last mile delivery by truck. Without such facilities, containers could also be transported from gateway ports to end-customers all the way by truck.
3. MODEL FORMULATION

Our mathematical model observed bi-objective optimization, minimizing transportation cost and transit time. Bi-objective optimization is more reasonable and realistic than single objective optimization. In real-life situations, decision makers often need to deal with conflicting objectives. Inclusion of more objectives into the model we obtain accurate information to the observed objects at the same time. Cost and transit time are the two most common considerations in transport planning problems.

It is analyzed transit time of container flow from the moment of the ship departure from the port of loading to the moment of the arrival container to the place of delivery in Belgrade, regarding the six different operators, five discharge ports and three different types of services on the sea legs. The total time includes waiting time of containers at the port of discharge, depending on the different modes of transport from port of discharge to Belgrade.

The transport cost was considered for each of the most commonly used types of containers in the container transport, and is based on the FOB term. Total cost includes, except the cost of transport from Shanghai to Belgrade, local costs in the port of discharge, customs clearance and handling costs. During inland transport it was used different modes of transport, and because of more appropriate comparisons of the costs of rail and barge with truck, it was included also handling costs at the terminal in Belgrade and final delivery to users by truck (local delivery).

Finally, in this model it was given a rank list and possibility to sort and make a list of the best possible solutions regarding minimization of transit time and transportation costs.

This section presents the model formulation and corresponding explanations are given as follows.

3.1 Definitions and notations

This section presents the model formulation and corresponding explanations are given as follows:

<table>
<thead>
<tr>
<th>Set</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>A set of nodes, let N = S ∪ E ∪ B, while S stands for origin port, E stands for gateway ports and B stands for place of delivery</td>
</tr>
<tr>
<td>A</td>
<td>A set of arcs connecting an origin to a gateway (first-leg arcs)</td>
</tr>
<tr>
<td>C</td>
<td>A set of arcs connecting gateways to place of delivery (second-leg arcs)</td>
</tr>
<tr>
<td>Decision Variable</td>
<td>Description</td>
</tr>
<tr>
<td>t_{ij}</td>
<td>Binary cost variable representing containers flow on first-leg arc, operator i to gateway j, t_{ij} ∈ {0,1}</td>
</tr>
<tr>
<td>l_{jk}</td>
<td>Binary cost variable representing containers flow on second-leg arc, gateway j, mode of transport k, l_{jk} ∈ {0,1}</td>
</tr>
</tbody>
</table>
tt\textsubscript{ij} \quad \text{Binary time variable representing containers flow on first-leg arc, operator i to gateway j, } tt\textsubscript{ij} \in \{0,1\}

tl\textsubscript{jk} \quad \text{Binary time variable representing containers flow on second-leg arc, gateway j, mode of transport k, } tl\textsubscript{jk} \in \{0,1\}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>Number of operator, (i \in {1,\ldots,6})</td>
</tr>
<tr>
<td>j</td>
<td>Number of port, (j \in {1,\ldots,5})</td>
</tr>
<tr>
<td>t</td>
<td>Type of container, (t \in {1,\ldots,3})</td>
</tr>
<tr>
<td>s</td>
<td>Type of service, (s \in {1,\ldots,3})</td>
</tr>
<tr>
<td>k</td>
<td>Mode of transport, (k \in {1,\ldots,3})</td>
</tr>
<tr>
<td>TSE\textsubscript{ij} \textsuperscript{s}</td>
<td>Transit time on first-leg arcs (expressed in days)</td>
</tr>
<tr>
<td>TEB\textsubscript{jk}</td>
<td>Transit time on second-leg arcs (expressed in days)</td>
</tr>
<tr>
<td>CSE\textsubscript{ij} \textsuperscript{t}</td>
<td>Transportation cost on first-leg arcs (expressed in $)</td>
</tr>
<tr>
<td>EX</td>
<td>Exchange rate (€ / $)</td>
</tr>
<tr>
<td>CPC\textsubscript{ij} \textsuperscript{s}</td>
<td>Port cost (expressed in €)</td>
</tr>
<tr>
<td>CEB\textsubscript{jk} \textsuperscript{k}</td>
<td>Transportation cost on second-leg arcs (expressed in €)</td>
</tr>
</tbody>
</table>

Objective functions:

Minimize Cost =

\[
\sum_{(l,j)\in A} (CSE_{ij} \frac{1}{EX} + CPC_{ij}) * t_{ij} + \sum_{(j,k)\in E} CEB_{jk} * l_{jk}
\]

\[ (1) \]

Minimize Time =

\[
\sum_{(l,j)\in A} TSE_{ij} \text{ts} * tt_{ij} + \sum_{(j,k)\in E} TEB_{jk} * tl_{jk}
\]

\[ (2) \]

Constraints:

\[
\sum_{(l,j)\in A} t_{ij} = 1
\]

\[ (3) \]

\[
\sum_{(j,k)\in E} l_{jk} = 1
\]

\[ (4) \]

\[
\sum_{(l,j)\in A} t_{ij} = \sum_{(j,k)\in E} l_{jk}, \forall j
\]

\[ (5) \]

\[
\sum_{(l,j)\in A} \sum_{s} tt_{ij} = 1
\]

\[ (6) \]

\[
\sum_{(j,k)\in E} t_{lk} = 1
\]

\[ (7) \]

\[
\sum_{l,s} tt_{ij} = \sum_{k} tl_{jk}, \forall j
\]

\[ (8) \]

Corresponding Explanations:

The objective function (1) minimizes total cost of container import flow through the transport network. They include transport cost on the first leg-arc (ocean costs), port cost and transport cost on the second leg-arc (cost of using inland vehicles – truck, rail and barge). The objective function (2) minimizes total transit time of container import from Shanghai to Belgrade. Constraints (3) and (4) define a single best solution for cost from a group of ordered pairs on the maritime and inland part. Constraint (5) selects the same port for the first and second leg-arc and defines one route from origin to place of delivery regarding transportation cost. Constraint (6) defines a single best solution for transit time on the ocean and depends of different type of service. Constraint (7) gives a single best solution for transit time on the second leg-arc. Constraint (8) selects the same port for the first and second leg-arc and represents one route from origin to place of delivery regarding transit time.
4. RESULTS AND DISCUSSION

In this section we analyze the results obtained by our developed bi-objective optimization model (BOOM), which minimize the time and cost of container import from Shanghai to Belgrade. BOOM was programmed in MATLAB and simulations were performed on an Intel Core i7-3612 QM 2.1 GHz computer. We use original input data regarding period jul-august 2013.

We observed five different scenarios and each of them gave us optimal solutions for various specified criteria. The results of our investigations are shown below:

Scenario 1:

We concern one objective optimization ("Min time") and the results are presented in Table 1. In this scenario the optimal transit time between Shanghai and Belgrade is 28 days using see and land legs together. The operator COSCO using China/Europe Shuttle Service – CESS and Adriatic Feeder Service – AFS service on the first-leg arc reach to the gateway port, Thessaloniki port and continues on the second-leg arc with truck to the final destination Belgrade. Regarding the optimal time the BOOM also shows us transportation costs for each type of container as well as the total distance.

Table 1 – Optimal transit time

<table>
<thead>
<tr>
<th>Port of loading</th>
<th>Shanghai</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator</td>
<td>COSCO</td>
</tr>
<tr>
<td>No.of transshipments</td>
<td>1</td>
</tr>
<tr>
<td>Service</td>
<td>CESS / AFS</td>
</tr>
<tr>
<td>Route</td>
<td>Shanghai-Ningbo-Shekou-Singapore-Port Kelang-Pireaus/Pireaus-Thessaloniki</td>
</tr>
<tr>
<td>Port of discharge</td>
<td>Thessaloniki</td>
</tr>
<tr>
<td>Mode of transport</td>
<td>Truck</td>
</tr>
<tr>
<td>Place of delivery</td>
<td>Belgrade</td>
</tr>
<tr>
<td>Optimal transit time</td>
<td>28 days</td>
</tr>
<tr>
<td>Rate 20 DV</td>
<td>2189 €</td>
</tr>
<tr>
<td>Rate 40 DV</td>
<td>3216 €</td>
</tr>
<tr>
<td>Rate 40 HQ</td>
<td>3253 €</td>
</tr>
<tr>
<td>Distance</td>
<td>17498 km</td>
</tr>
</tbody>
</table>

Scenario 2:

We analyze in this scenario one objective optimization ("Min cost") where the optimal transportation cost between Shanghai and Belgrade per each container (20 DV, 40 DV, 40 HQ) are respectively 1594 €, 2470 €, 2483 € using see and land legs together. These data are valid for the period August 2010. Since container transport on the Danube river (barge transport) from Belgrade to Constanza is not currently active, these data can be regarded as hypothetical. The first valid data regarding minimum price for transport between Shanghai and Belgrade base on FOB term per TEU is 1639 € and the results are presented in Table 2.

Scenario 3:

In this scenario we considered one objective optimization ("Rank list by time") and the results are illustrated in Figure 2. The objective criteria represent the full range of solutions assigning a price for each type of container to the each transit time on the range between 28 and 49 days. When the time is equal in some cases, BOOM gives us also the possibility to make a rank list by the second criteria (choosing different type of container). In terms of transit time between Shanghai and Belgrade, using different service of each of operators, 35 days is the most usually frequency.
Table 2 – Optimal transportation cost

<table>
<thead>
<tr>
<th>Port of loading</th>
<th>Shanghai</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator</td>
<td>MSC</td>
</tr>
<tr>
<td>No.of transshipments</td>
<td>1</td>
</tr>
<tr>
<td>Service</td>
<td>DRAGON / WEST MEDITERRANEAN</td>
</tr>
<tr>
<td>Route</td>
<td>Shanghai-Yantian-HongKong-Chiwan-Singapore-GioiaTauro/GioiaTauro-Rijeka</td>
</tr>
<tr>
<td>Port of discharge</td>
<td>Rijeka</td>
</tr>
<tr>
<td>Mode of transport</td>
<td>Rail</td>
</tr>
<tr>
<td>Place of delivery</td>
<td>Belgrade</td>
</tr>
<tr>
<td>Optimal rate 20 DV</td>
<td>1639 €</td>
</tr>
<tr>
<td>Transit time</td>
<td>35 days</td>
</tr>
<tr>
<td>Distance</td>
<td>17209 km</td>
</tr>
</tbody>
</table>

**Figure 2 – Rank list by time**

**Scenario 4:**

In this scenario we discussed one objective optimization ("Rank list by cost"). The objective criteria represent the full range of solutions for each type of container and showed as information about distance and transit time. Observing the results we spotted that the cost for 20 DV ranged between 1594 € – 3219 €, 40 DV between 2470 € – 4230 € and 40 HQ between 2483 € – 4297 €. The results which represent total cost per TEU are sorted by ascending order and provide us credible information about the transit time and their exact place in the ranking list on the transportation route between Shanghai and Belgrade. The first 50 solutions are illustrated in Figure 3.

**Scenario 5:**

It represents the most optimal route based on bi-objective optimization regarding cost and time together. Each of minimal objectives, cost and time have the same value (100). The rest of the costs and times are scaled. As the sum of these values we got the most optimal route where the percentage of significance of both variables,
cost and time are equal. The optimal solution for transport of 1 TEU from Shanghai to Rijeka is operator COSCO regarding the cost of 1657 € and the transit time of 31 day. The port of discharge is Rijeka and the mode of transport is rail.

Similar research in terms of testing the bi-objective optimization minimizing cost and transit time conducted Lam, J. S. L. and Gu, Y. [3] observing import and export container flow to and from inland China. The results and analysis offer managerial insights of the impact of trade-offs between cost and transit time, and the effect of different carbon footprint requirements on transport planning. Yang, X., Low, J. M. W. and Tang, L. C. [12] presents an intermodal network optimization model to examine the competitiveness of 36 alternative routings for freight moving from China to and beyond Indian Ocean. The proposed model is able to handle multiple and conflicting objective functions such as minimizing transportation cost, transit time and transit time variability while ensuring flow continuity and transit nodes compatibility among the rail, road, ocean vessel, airplane and inland waterway transports. The international intermodal routing problem is studied by Tsung-Sheng, C. [11] and it is formulated as a multi-objective multimodal multi-commodity flow problem (MMMFP) with time windows and concave costs.

5. CONCLUSION AND FUTURE RESEARCH

This paper analyzes the supply chain network with primary focus on import of containers from Far East (Port of Shanghai) to Serbia (city of Belgrade) through selected Mediterranean ports (Koper, Rijeka, Bar, Thessaloniki and Constanza), observing the six world’s largest container operators (Maersk Line, Mediterranean Shipping Company, CMA CGM, Evergreen Line, China Ocean Shipping Company and Hapag-Lloyd) with theirs different type of services. Serbia is hinterland country and container import from Far East to Serbia needs to use different transport modes on inland to link shipping transport in the sea leg including railway, barge and truck. Some customers prefer lowest freight rates while some others would rather pay more for a faster delivery. The main goal of this research is to provide an optimal route with shortest transit time and lowest transportation cost of container import from Shanghai to Belgrade.

We propose a mathematical model, which give us possibility to get reliable data of the minimal time and cost on the observed route per each type of container. The advantage of this model is that it gives us the possibility of observation beside of the optimal price and time, also the group of all possible solutions, which are ranked in ascending particular order. Period of observation in the mathematical model does not have to be time-limited.

The contribution of this paper shows that the experimental results are not only a scientific, since it can be applied in practice. Moreover we tested different scenarios, with a real input data and one hipotetical view. The application of the model is simple. It is recommended to managers who made a policy of the company,
in order to improve their businesses following the constant changes in the market and making reliable comparisons.

Further research is needed, because this research is recited only part of the problem. It can be extended in the future and can be imported with a lot of new nodes with the main objective to minimize time and cost of container flow.

6. ACKNOWLEDGEMENT

The study was carried out within the Project TP – 36027, "Software development and national database for strategic management of the development of means of transport and infrastructure in road, rail, air and water transport by European transport network models", financed by the Ministry of Education Science and Technological Development, Republic of Serbia.

7. REFERENCES


Abstract
The paper deals with inter-operational transport and material handling in production of interior’s parts for passenger vehicles. Organization of technological workplaces for the purpose of travel distance cut pursues cost reduction spending on inter-operational transport and material handling.

Keywords: Inter-Operational Transport, Material Flow, Layout, Production Technology, Space Layout

1. INTRODUCTION
The paper is devoted to a case study to standardize the flow of material in a limited production hall using material handling. The main goal of this paper is to show the relation between flexibility and performance of transport routes, assembly line mode of lean manufacturing. Original case study analyzes the internal flow of materials and is essentially one of the most important part of the optimization project, related to the application of lean production in a particular company from the automotive industry.

2. LAYOUT DESIGN ISSUES
Layout allocation, the spatial organization of production, non-production and storage facilities in the enterprise is undoubtedly one of the very important tasks because it has a direct impact not only on the work contained in this page of economic activity, but also on safety and last but not least, the social environment of the company [1,2].

Efforts related to optimizing and streamlining of processes have caused the creation of many algorithms that solve the problem of spatial arrangement (layout) [3,4,5]. These algorithms can be classified as optimal. The disadvantages of optimization algorithms are mainly high demands on computing time and the fact that large problems can not be solved optimally. Many approaches assume that all departments are equal and unchanging, fixed. In recent years, some authors have used also heuristic methods to solve the layout of large industrial buildings. Heuristics are specific to the issue being addressed and their solutions are very close to the optimal solution. However, the disadvantage is that the generated heuristics to solve the layout ignored the geometric constraints, such as the geometric shapes and surfaces of individual departments, which are the elements for creating essential layout [6,7].

2.1 Linear assignment problem
A commonly used intuitive introduction to the LAP (Linear Assignment Problem), is assigning n persons m tasks [8]. To assign each task is determined by the value of cargo (cost) cij assigning person i and work j. The aim is to assign each person to a single task and minimize the sum of the assignment costs, the total cost [9,10].

Mathematically, the linear assignment problem can be formulated:

$$\min \sum_{i=1}^{n} c_{i:j(i)}$$  (1)
over all permutations $\pi \in S_n$, where $S_n$ is the set of permutations $1, 2, \ldots, n$ and $j = \pi(i)$ is a task assignment to person $i$. It can be seen that each set of assignment is a permutation of set $n$ integers; and that is the reason why $n!$ ways in which $n$ tasks may be assigned to $n$ persons. For large values of $n$, it is the calculation according to conventional methods impossible. For instance, if it is necessary to assign $n = 10$ persons and ten tasks described above, it is necessary to examine $10!$, it means 3,63 million possibilities. For the layout design after all that is linear assignment problem (LAP) not appropriate.

2.2 Quadratic assignment problem

The quadratic assignment problem (QAP) is one of the most interesting combinatorial optimization problems. In the case of the QAP "matrix pricing" adds the "distance matrix". In QAP is specified price matrix $C = [c_{ij}]$, where $c_{ij}$ is a measure of the affinity between a person $i$ and person $j$. There are also $n$ possible offices that should be assigned to individuals.

Finally, the mentioned distance matrix is given $D = [d_{kl}]$, where $d_{kl}$ represents the distance between offices $k$ and $l$. Assume that person $i$ is assigned to office $p(i)$ and person $j$ is assigned to office $p(j)$. Then the costs associated with this assignment are identified as $c_{ij}d_{p(i)p(j)}$. The total cost of the assignments will be the sum of all $c_{ij}d_{p(i)p(j)}$ over all $i, j$. Optimal assignment will be the one in which the total cost is minimal.

If "distance" represents the number of direct communication between people ("face-to-face"), then the assignments that we require are those which minimize the total amount of distance you walk as a person. As in the case of LAP, there are $n!$ permutations, from which you need to select the optimal assignment. However, the key difference should be noted between LAP and QAP, which causes the QAP to be much more difficult to deal with. While the LAP, in which task assignment $j$ given to person $i$ was done independently on assignments to other employees, in case of QAP dependence exists. It means that if we consider the assignment of the person $i$ to the office $k$, it is necessary to consider allocation of all other persons who have a certain (non-zero) relationship with the person $i$.

Let's define $C$ and $D$ as two matrices of rank $n \times n$ so that $C = [c_{ij}]$ and $D = [d_{ij}]$. As stated above, we consider the set of positive integers $1, 2, \ldots, n$, and define $S_n$ as the set of permutations of $1, 2, \ldots, n$.

Then the quadratic assignment problem can be defined as:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij}d_{p(i)p(j)}$$

over all permutations $\pi \in S_n$, where $S_n$ is the set of permutations $1, 2, \ldots, n$.

QAP can be formulated as a problem of assigning a set of machines (or activities) to set of locations, with fixed costs for moving between locations and given flows between machines (activities).

Formally assigned $m$ machinery (activities) and $n$ locations, the matrix $D = [d_{ih}]$ with dimension $n \times n$, indicating the costs for moving between locations where $d_{ih}$ is the price for moving between location $i$ and location $h$, matrix $F = [f_{jk}]$ with dimension $m \times m$ characterizing flows between machines (transfers of data and material or personnel, etc.), where $f_{jk}$ is the flow between machine $j$ and machine $k$. Further we define $\pi$ as a permutation of the elements $\{1, \ldots, n\}$, where $\pi(i)$ is a machine that was assigned to location $i$.

The cost for the removal of material (moved data) between machines can be expressed as the product of the costs of moving between locations that were assigned to the machine and the flow between the machines: $c_{ih} = d_{ih}f_{\pi(i)\pi(h)}$.

Main goal is to find a permutation $\pi$ that minimizes the following objective function:

$$C(\pi) = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{p(i)p(j)}$$

The problem can be reformulated to produce the quadratic nature of the objective function.

Let's define $X$ as an permutation matrix of size $n \times n$ containing elements:

$$x_{ik} = \begin{cases} 1 & \pi(i) = k \\ 0 & j \neq \pi(i) \end{cases}$$
If we assign the machine \( j \) to the location \( i \) and also machine \( k \) with location \( h \) (then \( \pi(i) = j \) and \( \pi(h) = k \)), it means:

\[
\sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} f_{x(i, \pi(j))} \tag{5}
\]

The goal is to find a permutation matrix \( X \) where:

\[
\ldots \tag{6}
\]

is minimal, considering the limitations:

\[
\sum_{j=1}^{n} x_{ij} = 1 \tag{7}
\]

\[
\sum_{i=1}^{n} x_{ij} = 1 \tag{8}
\]

\[
x \in \{0, 1\} \tag{9}
\]

To apply the method to the QAP mass production environment with clearly defined unidirectional flow of materials with similar technological processes new method does not bring (surprising) results. In the case of unidirectional flow is the most appropriate spatial arrangement of logically sequential spatial alignment of individual processes behind each other in the direction of their course.

### 2.3 Issue of closed circuit (loop layout design)

It is a problem of the physical location of the machines to form a closed circuit (not necessarily need to be a circle or ellipse) in order to achieve a minimum of material handling. Transport of material between machines is only one direction, which from a practical standpoint means use of the belt (or other) conveyor, including the possibility of using automatic (self controlled) trucks or vice versa. Processes are set so that the processing machine \( j \) immediately follows the processing machine \( i \) and if the machine \( j \) is in the physical order in the circuit before the machine \( i \), stock is placed back into circulation (to conveyor) and continues to circle again another circuit before it gets to the machine \( j \). The criterion of schedule is the minimum number of circulation of the unfinished product (all manufactured products) around before it is completely finished.

![Figure 1 – Layout with closed circuit (own processing)](image)

This method is suitable for piece production; it can be used for small batch or mass production if the production program are products where technological progress requires repetitive operations on machines for products with large dimensions, produced in pieces or small series of large doses of machine tools due to capacity utilization and origination costs are unique in the business section.
2.4 Value Stream Mapping – VSM

Value Stream Mapping is an important step for the introduction of lean manufacturing principles and its performance substance. The main goal is to eliminate activities that do not add the product (from the customer's perspective) any value and the customer is obviously not willing to pay for those activities.

The procedure for mapping the value stream is based on four steps:

a) Selection of the product line
b) Representation of the current state
c) Representation of the future state
d) Realization

In the current business practice special method is applied most often in the form of a workshop, led by consultant who is a specialist in VSM. The length of the workshop is usually within one week. For this workshop we need to mention nomination of key members of units by management (not automatically department head) who have an overview of the processes that take place in the department. The objective of that week includes the above mentioned points a) to c), representation of the current state and future state design. The implementation process is roughly outlined and its implementation is then carried out according to plan, agreed by the management.

3. GROUP TECHNOLOGY AND ITS CHARACTERISTICS

Group Technology (GT) is looking for economies of scale of mass production which has the character of a batch production. At the beginning of the GT study the main goal was not to minimize costs but an effort to improve the management and control of manufacturing systems. GT may also be one of the critical elements in the case of restoration of the system of outdated and unproductive manufacturing companies.

GT combines the following elements into one continuous problem:

- Components are grouped into families with the same manufacturing requirements
- Small groups of machines are assigned to families of components
- Groups of operators are assigned to cells

The basic idea of the breakdown of production to the family of products and components originated from the grouping parts with similar processing characteristics into groups called "combined benefits" and tracing through functional layout support production planning. The base of GT cells can divide the production area into groups of machines in which they can complete all the required operations. Within its own GT, cells can then perform all operations preferably limited the implementation of the task.

When applying group technology, binary machine-component matrix can be used. Machine-component matrix is then defined as $A=\{a_{ij}\}$, where:

$$a_{ij} = \begin{cases} 1 \ldots \text{when component } "i" \in "j" \\ 0 \ldots \text{otherwise} \end{cases}$$

If machine-component matrix is used for solving problem then the objective is to create cells and assign components to these cells to ensure a high concentration values "1" in each of the diagonal matrices. Values "1" that are outside the diagonal block represent the need for transport between cells.

3.1 Methodology of cell formation

Used designation:

- $n$ number of components
- $m$ number of machines
- $p_{\text{min}}$ minimum number of cells
- $p_{\text{max}}$ maximum number of cells
- $r$ index of component type, $r = 1 \ldots n$
i,j  index of machine type
k   index of cells (families), k = 1,... p
Lf  lower limit of size (family components)
Uf  upper limit of size (family components)
Lc  lower limit of machine cell size
Uc  upper limit of machine cell size
A  = [ari], binary PMIN

\[
a_{ij} = \begin{cases} 
1 & \text{provided component } r \text{ requires elaboration on machine } i \\
0 & \text{otherwise}
\end{cases}
\]

nr  total number of necessary operations required component "r"
dr  production quantity of component "r"

TOTOPk  total number of operations in k cell
NOPk  total number of machines in k cell

For a pair of machines i and l using the following equation is calculated the index of similarity:

\[
s_{ij} = \frac{C_i + C_j}{T_i + T_j}
\]

where:

\[
C_i = \sum_{p=1}^{a} \sum_{j=1}^{n} w_{ip} c_{jip}
\]

\[
T_i = \sum_{p=1}^{a} \sum_{j=1}^{n} w_{ip} t_{jip}
\]

where:

t_{jip} = \begin{cases} 
0 & \text{provided } b_{jip} = 0 \\
1 & \text{1 or } ri \\
2 & \text{otherwise}
\end{cases}

c_{jip} = \begin{cases} 
0 & \text{if } b_{jip} = 0 \text{ or } bjlp = 0 \\
1 & \text{1 or } ri \\
2 & \text{otherwise}
\end{cases}

This is a sequential access in case when machines/components are grouped in two different phases. The first phase produces mechanical cells, based on the scale mentioned above. In the second phase, the component families are assigned to machine cells.

After arranging the machinery cells, components must be assigned to the cells to form a family of components. Each arranged cell is transformed into embryonic vector component. Transport number of each component vector with each component is calculated using the equation 2 and the vector components holding the largest value are assigned to a corresponding component of a embryonic vector.

The vector component is represented as (Pj = { P1j P2j ... Pij ... Pmj }), . Number of vector transports (sckj) of each component is embryonic component calculated from the equation:

\[
s_{ckj} = w_j \sum_{i=1}^{n} X_i
\]
where:
\[ X_i = \begin{cases} 
0 & \text{if } P_{ij} \text{ or } CS_{ik} = 0 \\
1 & \text{if } P_{ij} = 1 \text{ or } r_j \text{ and } CS_{ik} = 1 \\
2 & \text{if } P_{ij} \neq 1 \text{ or } r_j \text{ and } CS_{ik} = 1 
\end{cases} \]

Vector components with the highest number of transports (sckj) are associated with embryonic vector components and supplement the assignment component cells.

The flow within the cell or the amount of different elements is minimized by using a mathematical model. The model is formulated as follows:

\[
\min \sum_{i=1}^{n} \sum_{r=1}^{n} \sum_{j=1}^{n} \frac{(d_{ij}, b_{ij}, x_{irk})}{2} 
\]

where:

\[ b_{ijr} = \begin{cases} 
1 & \text{provided material components } i \text{ proceeds from machine } j \\
0 & \text{otherwise} 
\end{cases} \]

\[ x_{irk} = \begin{cases} 
1 & \text{provided machine } j \text{ components } r \text{ belongs to cell } k \\
0 & \text{otherwise} 
\end{cases} \]

\[ x_{jrk} = \begin{cases} 
1 & \text{provided machine } j \text{ components } r \text{ belongs to cell } k \\
0 & \text{otherwise} 
\end{cases} \]

\[ X_{ijk} = |x_{irk} - x_{jrk}| \]

\[ \sum_{k=1}^{p} x_{rk} = 1 \text{ for } r = 1, \ldots, n \]  

\[ x_{rk} = \begin{cases} 
1 & \text{provided component } r \text{ belongs to cell } k \\
0 & \text{otherwise} 
\end{cases} \]

\[ L_f \leq \sum_{r=1}^{n} x_{rk} \leq U_f \text{ for } k = 1, \ldots, p \]

\[ \sum_{i=1}^{m} y_{ik} = 1 \text{ for } i = 1, \ldots, m \]

\[ L_c \leq \sum_{i=1}^{m} y_{ik} \leq U_c \text{ for } k = 1, \ldots, p \]

Equation (15) minimizes movement between the cells for any part of machine configuration. Equation (16) ensures that there is a movement between the cells inside the machine for each product. Specified limits (17) and (19) ensure that component and machine can be assigned to only one cell. Equations (18) and (20) then limit the number of components and machines that can be assigned to one cell.

### 3.2 Creation of an algorithm

1. Beginning of an algorithm
2. Entering the number of machines
3. Specifying the number of components
4. Determination of condition: if there is then \( L_{C_{\text{min}}} = 2 \):
   \[
   L_{C_{\text{max}}} = \frac{\text{number of machines}}{L_{C_{\text{min}}} - 2} 
   \]
5. Verification of the correct assignment of machines to cells (maximum is 12 machines)
\[ L_{C_{\text{min}}} = \frac{\text{number\_of\_machines}}{12}; \quad L_{C_{\text{max}}} = \frac{\text{number\_of\_machines}}{L_{C_{\text{min}}}} \]

6. If the number of components, then
\[ L_{f_{\text{max}}} = \frac{\text{number\_of\_components}}{L_{f_{\text{min}}}} \]

7. Verification of the correct number of components, (should be 12)
\[ L_{f_{\text{min}}} = \frac{\text{number\_of\_components}}{12}; \quad L_{f_{\text{max}}} = \frac{\text{number\_of\_components}}{L_{f_{\text{min}}}} \]

8. Setting the minimum number of cells \( P_{\text{min}} = \text{Max} (L_{C_{\text{min}}}, L_{f_{\text{min}}}) \)
9. Setting the maximum number of cells \( P_{\text{max}} = \text{Min} (L_{C_{\text{max}}}, L_{f_{\text{max}}}) \)
10. Set \( L_f = L_{f_{\text{min}}} \) and \( U_f = 12 \)
11. Set \( L_C = L_{C_{\text{min}}} \) and \( U_c = 12 \)
12. Group machines using group technology GT.
13. Calculation of the flow inside the cell, point of efficiency, cost calculation.
15. Provided \( P_{\text{min}} = P_{\text{max}} \), proceed to step 18, otherwise continue with step 16.
16. Set \( P_{\text{min}} = P_{\text{min}} + 1 \)
18. Termination of the algorithm.

4. CASE STUDY

One of the key problems that were identified in performed causal analysis is increased volume handling of interior parts in the assembly area. This was in direct relation to the method of implementation (own assembly of automotive interior furnishing elements), which was carried on separate workplaces, one item for a single worker. The actual arrangement of the workplace and method of assembly have become essential parameters for optimizing the production process. From analysis of the assembly department dashboard resulted the need for its solution. Original assembly method was replaced by installing a device similar to a circle with a belt mounting. Change in the supply of assembly lines and the overall arrangement of the workplace had a positive impact on solving spatial organization.
Figure 2 – Graphic dependence between intensity of the material flow and distance from the machine. Custom processing.

Calculation of minimum (mentioned function) using Equation 15 is carried out successively after each iteration. We start from the initial deployment of logistical elements and changing them gradually (while respecting certain conditions, such as a specified position of any element) until we find out a solution that with more changes do not produce the required effect.

The optimal solution has been reached after the fifth iteration. For the original and newly proposed solutions were processed diagrams (pic.3, pic.4). Various iterations and resulting values are listed in Tab.1. The table shows that using application of group technology method reduction was achieved in the volume of parts engineered to almost a quarter compared to the initial state.

Table 1 – Various iterations and resulting values

<table>
<thead>
<tr>
<th></th>
<th>New layout</th>
<th>Iteration 1</th>
<th>Iteration 2</th>
<th>Iteration 3</th>
<th>Iteration 4</th>
<th>Iteration 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall transport capacity [ks*m]</td>
<td>2 340 900</td>
<td>690 000</td>
<td>642 000</td>
<td>598 000</td>
<td>536 000</td>
<td>510 000</td>
</tr>
<tr>
<td>Overall transport track [m]</td>
<td>11 705</td>
<td>3 450</td>
<td>3 210</td>
<td>2 990</td>
<td>2 680</td>
<td>2 550</td>
</tr>
<tr>
<td>Time required [min]</td>
<td>4830</td>
<td>1870</td>
<td>1710</td>
<td>1690</td>
<td>1590</td>
<td>1360</td>
</tr>
</tbody>
</table>

Figure 3 – Production hall. Current status with drawn material flow. Custom processing.

Figure 4 – Production hall with extension. The proposed state and placement of machines, including material flow.

5. CONCLUSION

The paper is an example of analysis and subsequent production optimization (in light of time) of interior’s parts for passenger vehicles. Original paper focused on material flow optimization contributes not only to reorganization of workplace space layout but also has been an impulse for new workplace layout of assembly including an implementation of automatic identification used barcodes. It’s evident, that use of system thinking and process approach along with logistics pieces of knowledge application can stand significant
contribution not only to economics but also to working environment improvement, employees satisfaction thereby also contribution to company competitive advantage enhancement.

6. ACKNOWLEDGEMENTS

This work is a part of research project VEGA 1/0922/12 Research of effect of material characteristics and technological parameters of conveyor belts on size of contact forces and resistance to motion in pipe conveyors with experimental and simulation methods. This work is a part of research project VEGA 1/0258/14 Study of input parameter relations for interoperable transport efficiency based on mathematical model application. This work is a part of research project APVV SK-CZ-2013-0169. The article was prepared within the invitation OPVaV-2012/2.2/08-RO named "University Science Park TECHNICOM for Innovation Applications with the Support of Knowledge-Based Technologies"- code ITMS 26220220182.

7. REFERENCES

EVALUATION OF TRANSPORT RESEARCH BETWEEN U. S. STEEL KOŠICE EMPLOYEES IN AN INTEGRATED TRANSPORT SYSTEM

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Abstract
The contribution deals with the survey of introduction of a new integrated transport system on the stop Hutníky on the railway line between Moldava nad Bodvou city and Košice. The paper summarizes observed results and findings of the survey. Based on the data collected from the survey there is an evaluation of usefulness of the new integrated transport system. The outcome of this work is also the database created in MS Excel functional template. The found results are summarized in conclusion.

Keywords: U. S. Steel, s.r.o., Integrated Transport System, Transport survey, Hutníky, Košice

1. INTRODUCTION
With the increasing fuel prices and environmental pollution, public transportation system is essential to the existence of people since it satisfies basic needs of the society. These transportation services must be able to compete with individual passenger transport in price, convenience and time. The integrated transport system (ITS) can offer a solution to this problem. The key to the success of this system is the design of an optimal schedule and continuity of connections at reasonable fares. The work contains the procedure of necessary steps for the introduction of new ITS on route Moldava nad Bodvou city – Hutníky – Košice (M-H-KE). Conclusion contains the survey evaluation of ITS on the route M-H-KE.

2. THE INTRODUCTION OF THE NEW INTEGRATED TRANSPORT SYSTEM (ITS) ALONG MOLDAVA NAD BODVOU CITY – HUTNíKY – KOŠICE (M-H-KE)
The main objective of this sophisticated network of different forms of public transport is to stop the rapid growth of individual automobile transport and reduce its negative impacts on human health and the environment (emissions, noise, high accident rate etc.). Currently, a great number of people are moving to suburban neighborhoods and communities in the vicinity of large cities. Thus the need for daily commuting to work or school arises, which in practice is an enormous number of passenger cars on the road around the same time. Integrated Transport offers quality, convenient, fast and interval public transport for residents, which could replace the individual transport, for example by car. [1]

The share of private transport on the road should start falling after finishing, synchronising and complete system startup. This unburdens mainly the roads leading to the city centre and and it is expected that there will be less traffic congestion in the city. It will also reduce the burden on the environment because the transport system in which rail transport is also involved is more environmentally friendly. [2]
The means to reach the objective:
synchronization of routes, timetables and fares of several forms of public transportation
(railway, urban public transport, regional bus service)

Social benefits:
Elimination of adverse traffic situations in large urban areas emerged as a result of the increase of individual passenger transport, reduction of accidents, time loss in transport and environmental degradation.

To introduce ITS along the route M-H-KE, we have to proceed according to several steps below:

FIRST STEP
Electrification of the railway line Haniska pri Košiciach – Moldava nad Bodvou town:
The objective is to achieve improved passenger transport comfort by improving driving dynamics, by better route facilities and also by better route concurrence of passenger and freight trains on electrified section Haniska – Veľká Ida – Moldava nad Bodvou town. Electrification of routes creates a precondition for connecting this line with the upcoming integrated system of passenger rail transport Košice. Representation necessary electrification of the railway line we can see in Figure 1. The target state solution is the completion of regional bus transport lines from the western part of the Košice- okolie region at the proposed Terminal Moldava nad Bodvou town, allowing passengers a direct change to the carrier rail transport heading to the railway station in Košice. [3]

SECOND STEP
Construction of the transport terminal in Moldava nad Bodvou town.
Terminal of public and private transport is a site where rail and road transportation will meet.

Access to the terminal sites from the city centre will be possible along the existing local communication through the railway line. Current condition of the stop in Moldava nad Bodvou and visualization of the new terminal which forms the bus and the railway station you can seen in Figure 2. [5]
3. DESCRIPTION OF THE SURVEY

Evaluation of questionnaires was made using a template from which we drew data. We used Microsoft Office Excel 2007 for the evaluation of the questionnaires. We entered employee information to the created template manually. To create the template sequence, they are entered manually employee information. Using automatic filters we can set specific establishment, residence, means of transport used to work, working hours, age and usability of ITS in the template. [6]

To simplify the evaluation, we divided villages and towns into different areas from Ž1-Ž15 and rail routes from O1-O9 as we see in Figure 3.

We evaluated the rail route Ž7 and Ž8 (M – H – KE) in our contribution.
4. EVALUATION OF THE ITS SURVEY ON THE ROUTE M-H-KE

Data used in the contribution come from the traffic survey conducted among U.S. Steel Košice (USSK) employees. The traffic survey was conducted on 10th of February 2013. A total of 8052 questionnaires were collected out of 10 050 people, representing 80.1% of the total number of USSK employees.

Evaluation of route Moldava nad Bodvou town – Hutníky.
The included municipalities on this route are Moldava nad Bodvou, Mokrance, Čečejovce, Paňovce, Debradě, Čestice and Veľká Ida. Total number of USSK employees from this region is 895. [6] Usability of the proposed system for the given area is schematically shown in Figure 4.

Figure 4 – Usability of ITS by USSK employees from municipalities on the route Moldava nad Bodvou – Hutníky

Capacity schedule for the given areas constitutes the second part of the survey evaluation.

Capacity plan is divided into individual working shifts of USSK employees who are interested in using new ITS from their residences and back. Detailed schedule is in the table 1 based on which we can propose harmonizing of routes and service schedules.

Table 1 – Capacity Schedule from Moldava nad Bodvou town – Hutníky according to the working shifts of USSK employees

<table>
<thead>
<tr>
<th>To USSK</th>
<th>Workdays</th>
<th>Free days</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00</td>
<td>364</td>
<td>99</td>
</tr>
<tr>
<td>7:00</td>
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<td>8:00</td>
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<tr>
<td>22:00</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>6:00</td>
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<td>99</td>
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<tr>
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<td>37</td>
</tr>
<tr>
<td>22:00</td>
<td>62</td>
<td>62</td>
</tr>
</tbody>
</table>

Table 2 – Capacity plan from Košice – Hutníky according to working shifts of USSK employees

<table>
<thead>
<tr>
<th>To USSK</th>
<th>Workdays</th>
<th>Free days</th>
</tr>
</thead>
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<td>7:00</td>
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<td>8:00</td>
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<td>22:00</td>
<td>227</td>
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<tr>
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<td>X</td>
</tr>
<tr>
<td>18:00</td>
<td>113</td>
<td>113</td>
</tr>
<tr>
<td>22:00</td>
<td>227</td>
<td>227</td>
</tr>
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</table>

Evaluation of the route Košice – Hutníky
The included municipalities on this route are Košice – Ťahanovce, Košice – Dargovských hrdinov, Košická Nová Ves, Košice – Staré mesto, Vyšné Opátske, Košice – Juh, Košice – Nad Jazerom, Krásna, Krásna nad Hornádom, Barca, Šebastovce. Total number of USSK employees from this region is 3477. [7] Usability of the proposed system for the given area is schematically shown in Figure 5.
Detailed schedule is in the table 2 based on which we can propose harmonizing of routes and service schedules.

5. CONCLUSION

Integrated transport system in the current condition of public transport presents a means of providing improvements in transport service.

The work includes evaluation of the number of employees from route Moldava nad Bodvou tow – Hutníky – Košice. It specifies the number of people who are / are not interested in taking advantage of integrated transport system. The second important result is the number of people who are interested in using integrated transport system according to working shifts. 39% of USSK employees of the total number of people from route Moldava nad Bodvou city – Hutníky is interested in using new ITS daily. Interest of employees on the route Košice – Hutníky reached 58%. A detailed schedule of ITS use is shown in Fig. 4 and Fig. 5. The capacity plan of USSK employees who are interested in the use of ITS according to individual shifts is shown in Table 1 and 2. As we see, USSK employees would like to use the new ITS, however we need to adapt it to people’s requirements.

This new way of transport with optimal settings of integrated transport system connections and competitive prices has a huge potential and perspective in area of travelling.

The importance of the research is to highlight the need for ITS by people. In the article, we evaluated specifically the route Moldava nad Bodvou city – Hutníky – Kosice.

This work is a part of research project VEGA 1/0922/12 Research of effect of material characteristics and technological parameters of conveyor belts on size of contact forces and resistance to motion in pipe conveyors with experimental and simulation methods. This work is a part of research project VEGA 1/0258/14 Study of input parameter relations for interoperable transport efficiency based on mathematical model application.

6. LITERATURE

A SOLUTION FOR CONTAINER TERMINAL QC SCHEDULING CONSIDERING GROUPED TASKS AND OPERATIVE ZONE LIMITS

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Abstract
Scheduling of quay cranes on container terminals has been subject of many research papers. The main focus of those researches is minimizing the loading/unloading operations of a vessel. In this paper we are looking for applicable solution for mid-size container terminals with particular focus on practical problems where quay length and tight space on a vessel may be an issue. Grouping of the tasks, depending on container position on the vessel, have an impacts on interference between cranes, which affects the optimum function. On the other side, the quay length for free movement of the cranes may be an issue on certain terminals. We propose single solution based on mixed integer linear programming that combines existing research achievements with author’s own approach in container terminal optimization development.

Keywords: quay crane scheduling, container terminals, crane interference, mixed integer linear programming

1. INTRODUCTION
Container terminals are subject of numerous scientific studies that aim to improve the efficiency and quality of services. The reason for such interest is the continued growth of container traffic in the world and permanent adaptation to customer requirements. Within the container terminal subsystems [1], several tactical logistic problems exist [2]. One of the primarily problem of the seaside subsystem is the Quay-Crane Scheduling Problem (QCSP). That is how to find out the best scenario for loading/discharging of cargo from the vessel and organize crane operations. More specific, the optimum assignment of the quay cranes to particular handling tasks has to be determined. In the most cases the objective is to minimize the transshipment process and to complete the vessel operations within the expected time-frame.

Apart from the shipping companies and logistic providers, there is a strong interest of terminal operators to improve their service performances and resource allocation. That is not only the case for big size terminals. Also mid-size terminals, with annual throughput up to 1 million TEUs, need to improve the system performance and to cope with existing infrastructure and equipment limitation [3]. In many cases, when the volume of container operations exceeds critical number, there is not possible to solve the operational problems empirically.

The QCSP has been studied among many researchers from different perspectives. Among others, there are Daganzo [4], Kim and Park [5], Liu et al. [6], Lim et al. [7, 8], Zhu and Lim [9], Lee et al. [10], Meisel [11], Meisel and Bierwirth [12]. Some of these papers are theoretical important and some of that are commercially motivated especially considering specific requirements from the large far-east container ports service market. However, there is a shortage of papers that are focused on specific handling issues like grouping of tasks and space-operation limits. In this paper we propose all-in-one solution based on high utilization of space and crane workload.

2. PROBLEM DEFINITION
The QC operation schedule is determined according to container handling demand, for a set of cranes assigned to each particular vessel. The total demand for transhipment determines the transport operation workload to be carried out. With the constant productivity of a quay crane (number of cycles per hour) and with known workload quantity, it is possible to calculate processing time for each consecutive task.
 Generally, loading and unloading operations can be structured into the tasks. Each task represents one or more QC jobs located on the ships bay according to container stowage plan. The goal is to assign cranes to tasks in an optimal way according to predefined criteria. We propose model that solve QCSP taking into account the following criteria:

- minimum handling makespan, that is completion of the last consecutive task
- early release of QCs
- minimum space-span inside QC operational zones

In order to achieve these goals we use specific methodology which includes: task sharing algorithm, tasks grouping and operational zone limits.

Task sharing algorithm allows split of a task during handling process. That means a crane may leave the job before finish entirely loading/unloading operations associated within the task. In that case, another crane may be scheduled to that job to complete the operations. However, only one QC may work on the same bay (or group of bays) at the same time, due to space constraints. The idea behind is to get balanced workload among the QCs and to achieve higher utilization rates. Splitting of task is one of the problem solution proposed by Liu et.al. [6] and elaborated under so called “vessel-level models”. There, authors highlighted the negative impact where extensive partitioning of tasks may occur, increasing the unproductive moving of QCs. Our approach is therefore to squeeze QC movement in the operational zone and to minimize movement of cranes alongside quay, but without impact on total vessel processing time.

Transshipment processes can be divided into an arbitrary number of tasks. Theoretically, each container can be considered as one task. In practical terms that it is unnecessary and it would require more complex problem solution. Containers on the same bay may be represented as one QC job. More than one job on adjacent bays may be grouped into the so called bay clusters represented by only one task, without influence on working performance. This is the case because not more than one QC can work on the specific tasks inside the cluster due to space limitation. Cluster division has been more detailed explained by Kim and Park [5]. Figure 1 shows schedule scenario for four tasks processed by two QC.

**Figure 1** – Operation zones, crane travel limits and cluster boundary in a QCSP scenario
Quay cranes are represented by different halftone of grey color and each task by rectangle on time-space diagram. All rectangles have the same height corresponding to overall length of each QC including safety distance between them. Position of QCs on y-axis is relative to bay numbers on the vessel. Small bay numbers from the left side of y-axis represent cluster boundary and cluster ranges for each group of jobs that are joined in one common task. Each QC may be in any time located in any position inside cluster boundary. Therefore, safe environment should be guaranteed to avoid interference between them and possible collisions when two adjacent cranes are located on their boundary positions. On the Figure 1 dashed lines display required safety distances between QCs.

Size and boundary of the cluster depend on range between minimum and maximum bay locations as part of it. There are three parameters defining position of a task relating to the vessel:

- \( h_{i}^{\text{mid}} \) - central position (bay number) of the cluster task \( i \) on the vessel
- \( h_{i}^{\text{lo}}, h_{i}^{\text{up}} \) - lower and upper boundary (bay numbers) of the cluster task \( i \) on the vessel

Inside each cluster more than one loading/unloading job may exists but all of them may be represented by one common task. The model for QCSP solution have to take into consideration cluster as the whole and its boundary when consider position and movement of QCs and interference constraint between them. Jobs on adjacent bays can be easily grouped into one task but concentration of tasks at evenly distributed container across the ship bays may require special heuristics.

Movement of cranes alongside quay may cause interference to neighboring vessel operations. Also, movement is limited by the length of crane rail tracks. For example, in a case when second order QC is engaged in the lower bays, the first order QC may be positioned far below operational zone. Therefore, travel limits should be inserted in the model to avoid non-feasible solutions. Definition of operational zone for each QC is important for operational planning of other terminal resources and for restriction of unnecessary QC movement.

### 3. MODEL FORMULATION

Our QCSP solution model is based on the following assumptions:

- Task should be marked successively from lower to higher number relative to bays, from bow toward stern of the vessel.
- Cranes must satisfy the safety distance criteria and non-crossing constraint. Also there must be enough space between working cranes for any mid-ship crane that are in idle state.
- There must be enough space on the quay for positioning the crane outside the operational zone, but inside the travel limits, during QC idle state.
- There is no optimal solution guaranteed when the task priority system is set up such that higher bay task must precede the lower bay task.
- There is no solution exists in the above case with only one QC in the system.
- Optimal solution may result in extensive partitioning with many short tasks that may lead to segregation of terminal resources in other terminal subsystem. The solution for that is setup of constant \( p^{\text{min}} \) with minimum acceptable value for task processing.
- Processing time for each task has been known in advance according to average production rate; hatch cover manipulation time and preparation time have to be included in processing time.

For the mathematical formulation we define three sets of data: \( A = \{1,2,...,a\} \) is set of tasks with index \( i \in A \), \( Q = \{1,2,...,q\} \) is set of quay cranes with index \( k \in Q \), \( R = \{(1,2), (1,3), \ldots, (i,j)\} | i, j \in A, i \neq j \) is set of task pairs according to Kim and Park [5]. Input parameters and output variables used in the model are shown in Table 1.
The objective function minimizes processing time of the vessel or handling makespan, completion time of QC and movement area of QC with following expression:

$$Min Z = \omega_1 T + \omega_2 \sum_{k=1}^{Q} (c_{sk} - p_{sk}) + \omega_3 \sum_{k=1}^{Q} (\psi_{k}^{up} - \psi_{k}^{lo}) v^{-1}$$

1. subject to:

$$c_{sk} \leq T \quad \forall i \in A, \forall k \in Q$$

$$s_{sk} + p_{sk} = c_{sk} \quad \forall i \in A, \forall k \in Q$$

$$\sum_{i=1}^{A} p_{sk} = p_i \quad \forall i \in A$$

$$p_{sk} \leq p_{sk} x_{sk} \quad \forall i \in A, \forall k \in Q$$

$$x_{sk} \leq M p_{sk} \quad \forall i \in A, \forall k \in Q$$

$$p_{sk} \geq p_{min} x_{sk} \quad \forall i \in A, \forall k \in Q$$

$$M - M x_{sk} + \psi_{sk}^{up} \geq h_{sk}^{up} x_{sk} \quad \forall i \in A, \forall k \in Q$$

$$M x_{sk} - M + \psi_{sk}^{lo} \leq h_{sk}^{lo} x_{sk} \quad \forall i \in A, \forall k \in Q$$

$$c_{sk} - p_{sk} \geq c_{sk} + b + v^{-1} (h_{sk}^{mid} - h_{sk}^{mid}) - M \left[ 2 - (x_{sk} + x_{sk}) \right] \quad \forall i, j \in A \mid h_{sk}^{mid} \leq h_{sk}^{mid}, \forall k, l \in Q \mid k < l$$

$$c_{sk} - p_{sk} \geq c_{sk} + b - M \left[ 2 - (x_{sk} + x_{sk}) \right] \quad \forall i, j \in A \mid h_{sk}^{mid} \leq h_{sk}^{mid}, \forall k, l \in Q \mid k < l \wedge (h_{sk}^{lo} - h_{sk}^{up}) < d(l - k)$$

$$c_{sk} - p_{sk} \geq c_{sk} + b + v^{-1} (h_{sk}^{mid} - h_{sk}^{mid}) - M \left[ 2 - (x_{sk} + x_{sk}) \right] \quad \forall i, j \in A \mid h_{sk}^{mid} \leq h_{sk}^{mid} \wedge i < j, \forall k \in Q$$

$$\psi_{sk}^{up} - \psi_{sk}^{lo} \geq d(l - k) \quad \forall k, l \in Q \mid k < l$$

The efficiency of proposed model for QCSP solution is tested on the following example: there is seven tasks grouping, travel limits and operational zone requirements. Model formulation in former paragraph, based on sharing task algorithm, has some characteristic features.
The objective function minimizes processing time of the vessel or handling makespan, completion time of
\( \omega \)

\[ \begin{align*}
\psi_k^w - \psi_k^w & \geq d(l-k) \quad \forall k, l \in Q \mid k < l \\
\psi_k^w & \geq B^w \quad \forall k \in Q \\
\psi_k^w & \geq B^w \quad \forall k \in Q \\
x_{ik} & \in [0,1], c_{ik} \geq 0, p_a \geq 0 \quad \forall i \in A, \forall k \in Q
\end{align*} \]

(14)
(15)
(16)
(17)

Basically, expression (1) uses core formulation of Kim and Park [5] but with different assignment logic and
decision variable structure. Instead of 3-dimensional binary variable, we use 2-dimensional binary decision
variable \( x_{ik} \) to specify which QC is assigned to which task. Assignment logic is based on task sharing
algorithm [6]. Relations between coefficients \( \omega_1, \omega_2 \) and \( \omega_3 \) have to satisfy the following criteria:
\( \omega_1 \gg \omega_2 \) and \( \omega_1 \approx \omega_3 \). Constraints from (2) to (17) are based on predefined assumptions, cluster task
grouping, travel limits and operational zone requirements.

4. APPLICATION EXAMPLE

Model formulation in former paragraph, based on sharing task algorithm, has some characteristic features.
That is one-way direction of movement from bow to stern of the vessel and high utilization of the QC.
Movement of QC is one-way when there is no change in travel direction alongside quay during handling
utilization. However, only standard crane-to-task algorithm has been targeted. It should be emphasis that
one-direction movement does not have effect on operations within the cluster task and corresponding jobs
between cluster boundaries.

The efficiency of proposed model for QCSP solution is tested on the following example: there is seven tasks
correspond with grouped jobs in the particular cluster. Each task has predetermined transport demand
expressed in number of containers for loading/unloading. For each task, cluster boundary has been set up as
well as expected process time according to predetermined production rate. Input parameters data and output
values for the example are shown in Table 2. The graphical representation of the optimal solution is shown in
Figure 2.

| Table 2 – Problem example and optimal solution for QCSP for the system of 3 QC |
|---------------------------|---------------------------|
| **Input data**            | **Output data**           |
| No. of containers         | \( p_i \) | \( h^lo \) | \( h^{mid} \) | \( h^{up} \) | \( s_{ik} \) | \( p_{ik} \) | \( c_{ik} \) |
| Task1                     | 10   | 22   | 11   | 12   | 13   | 0   | 22   | 22   |
| Task2                     | 21   | 47   | 11   | 12   | 13   | 22  | 47   | 69   |
| Task3                     | 27   | 60   | 25   | 28   | 31   | 0/70| 21/39| 21/109|
| Task4                     | 14   | 31   | 39   | 44   | 49   | 22  | 31   | 53   |
| Task5                     | 23   | 51   | 60   | 65   | 70   | 0/55| 15/36| 15/91|
| Task6                     | 23   | 51   | 60   | 65   | 70   | 15/91| 33/18| 48/109|
| Task7                     | 27   | 60   | 81   | 84   | 87   | 49  | 60   | 109  |
| Operational zone for QC1 (begin/end/travel-time) | 11   | 31   | 1.33 |
| Operational zone for QC2 (begin/end/travel-time) | 25   | 70   | 3.00 |
| Operational zone for QC3 (begin/end/travel-time) | 60   | 87   | 1.80 |
| Objective function (Z)    |      |      | 118.30 |
| Makespan \((T)\)          |      |      | 108.90 |
| Total utilization of QCs (system of 3QC) |      |      | 0.946 |
Figure 2 – Optimal solution for QCSP problem example for the system of 3 QC

Graphical representation of the optimal solution (Figure 2) demonstrates the efficiency of the proposed model based on share-task algorithm with 3 QC engaged in handling process. Three tasks, namely 3, 5 and 6 has split by the model and processed by 2 QC respectively. As consequences we’ve got very high utilization rate for each QC and total for the system. Partitioning problem is not an issue because we can regulate its level by the parameter $p_{\text{min}}$ which has been arbitrary set to value of 15.

For the reliability of the model it is very important to satisfy all operational constraints. Again, Figure 2 shows very well how the model copes with the interference constraints between QCs and corresponding cluster boundaries. At the example, tasks 3 and 4 although on the first look it seems that they may be processed simultaneously by two QC, they must not. The reason is that upper cluster limit of task 3 and lower cluster limit of task 4 overlap and therefore may lead to collision between cranes while they are moving within cluster boundary. Therefore, task 3 and task 4 cannot be processed simultaneously, that is exactly what the model did when calculated optimal schedule solution.

5. CONCLUSION

In this paper we present a solution for Quay Crane Scheduling Problem based on task sharing algorithm, with cluster tasks structure and operative zone limits. The objective of optimization is minimization of vessel service time and crane efficiency. The proposed model based on mixed integer linear programming is suitable for solving tactical problems of resource management and may be used for decision making also on mid-size container terminals where the quay space may be an issue. Applicability of the model has been demonstrated on a practical example with three QCs in the system. Important characteristics of the model are optimal processing time given with high utilization rates of QCs.
6. REFERENCES

ROBUST STOCHASTIC SCENARIO-BASED APPROACH TO CLOSED-LOOP SUPPLY CHAINS WITH UNCERTAINTY IN SUPPLY, CUSTOMER DEMANDS AND RETURN RATES

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Abstract

In this paper, a two-stage stochastic programming approach is used for analyzing the behavior of Closed-Loop Supply Chains (CLSCs) with uncertainty in supply, demands and return rates when designing and planning such systems. In addition, as part of the planning problem, this approach takes into account the capacity constraints on production, distribution and storage, as well as operational and environmental costs, and considers, by means of scenarios, the simultaneous integration of the three uncertainty sources. Since in stochastic approaches an important aspect to be considered is the selection of the objective function, this paper includes three performance measures that search for profit maximization. Thus and with the objective of achieving more robust solutions, besides the expected profit, two other objective functions that include risk criteria are also considered. The effectiveness of the proposed approach is established by means of an example considering different states of supply, demand and return rates. Thus, employing the stochastic programming approach, novel insights related to the behavior of CLSCs and the flow of returned products are derived.

Keywords: Mathematical modeling, stochastic approach, risk criteria, design and planning, uncertain closed-loop supply chain

1. INTRODUCTION

Traditionally, forward supply chain networks are strategically designed and planned to satisfy certain expected demand levels. Nevertheless, the current market globalization, environmental deterioration, resources shortage and new regulations lead companies to consider in their businesses the forward and reverse networks coupled in a closed mode, in order to improve cost-effectiveness and environmental benefits caused by the reuse of resources.

Given the volatility associated with the operation of supply chains, the use of stochastic formulations is unavoidable. Thus, these approaches should account for an important aspect that is the capability of addressing disturbances, such as the supply, demand and return rates fluctuations, by decreasing the influence they produce on the CLSC performance. Few papers have been proposed considering stochastic programming approaches applied to CLSCs with uncertain parameters. Some of the most recent papers considering stochastic programming approaches applied to CLSCs are Vahdani et al. (2012)[1], Zeballos et al. (2012)[2], Amin and Zhang (2013)[3], Cardoso et al. (2013)[4] and Hamed, S., et al. (2014)[5]. It is important to note that several of the above mentioned papers addressing uncertainty issues use a two-stage stochastic methodology where two types of decision variables are considered: the first stage (design) variables and second stage (control) variables representing the decisions that are determined before and after realization of uncertain parameters, respectively (Birge and Louveaux, 1997[6]; Dantzig, 1955[7]). Nevertheless, most of the two-stage stochastic formulations are risk-neutral since they only consider expected costs/expected profit in the objective function.
2. PROBLEM STATEMENT

This paper addresses the design and planning problems presented by a CLSC that involves a set of products grouped according to their salvage grade (e.g., fully reusable, partially reusable and non-reusable). The network considered includes suppliers ($I_s$), factories ($I_f$), warehouses ($I_w$), distribution centers ($I_{dc}$), customers ($I_c$), collection centers ($I_{cc}$), dismantlers ($I_d$), repairing centers ($I_{rc}$), final disposal locations ($I_{fd}$) and decomposition centers ($I_{dp}$). Figure 1 provides a schematic representation for the general CLSC under consideration.

The rates of products flowing in the reverse network, which depend on the salvage grade, are taken as suggested in Paksoy et al., (2011)[8]. Collection centers receive end-of-life, broken and defective products from the customers with a return rate of $\alpha$. The $\beta$ and $(1 - \beta)$ denote the flows of used products in collection centers that are sent to repairing centers and dismantlers, respectively. The $\chi$ and $(1 - \chi)$ specify the rates at which the repaired products are carried to distribution centers and warehouses from collection centers. The parameter $\delta$ and their complement $(1 - \delta)$, denote the fractions of products in dismantlers that are transported to decomposition centers and final disposal. Finally, some components of the returned products are transported to suppliers ($\epsilon$) and production plants $(1-\epsilon)$. In addition, the following assumptions are considered in the CLSC:

1. The planning horizon is divided into several time periods.
2. Not all products are recovered after being purchased by customers.
3. Recycled products are treated equally to new ones.
4. Transportation operations between any pair of entities can be performed using different transportation modes.
5. Uncertainty is associated with customer demand, minimum and maximum raw material supply as well as return rates.
6. Locations and capacities of network entities are known in advance.
7. Network entities can be opened/closed at the beginning of any time period.
8. The distances between entities and transportation capacity are known and fixed.
9. Transportation, purchasing, storage, facilities and estimated CO2 emissions costs are deterministic.
10. The unit profit of recycled products is also deterministic.
11. The incentive for recycling returned products is known in advance.

The objective of the study is to maximize CLSC profit by using optimum network design for production and recovery, optimizing the levels of processing, storage, transportation and emissions of new and returned products. The amount of products grouped according to their salvage grade is considered.

![Figure 1 – Schematic representation of the general CLSC considered](image-url)
3. FORMULATION

To address the above problem a mixed-integer two-stage linear programming model was developed. As stated above, uncertainty is associated with supply, demand and return rates. In principle these quantities can be characterized by their distribution functions, but in this paper the uncertainty is represented instead by several realistic states. Therefore, it is assumed the existence of different discrete set of outcomes/events to describe the possible values of the uncertain parameters. The combination of events associated with the three uncertain parameters lead to a new set of outcomes, which describe simultaneously supply, demand and return rates.

It is important to note that the two-stage approach allows the representation of uncertain parameters, which is an advantage with respect to deterministic formulations. Uncertainty is modeled as a two-layered scenario tree, where supply, demand and return rates are considered as stochastic data processes that, after their occurrence, remain with the same value during the entire planning horizon (see Figure 2). Thus, each node in the scenario tree represents a possible market state, associated with a set of data.

Two kinds of decisions are considered in the two-stage formulation. Due to the uncertainty in supply, demand and return rates, the decisions on opened/closed entities are made before knowing which actual event will take place. However, planning decisions connected with transportation, storage and emissions will be only made after the uncertain parameters are revealed, which is the reason for them to be called recourse decisions. The model uses five types of variables: \( x_{i,j,p,r,t,s} \) and \( z_{i,r,t,s} \) are continuous variables denoting the amount of product \( p \) transported from entity \( i \) to entity \( j \), at time \( t \), for scenario \( s \), and the amount of products stored in entity \( i \), at time \( t \), at scenario \( s \), respectively; \( y_i \) is a binary variable indicating whether entity \( i \) is included or not in the network; \( w_t \) is a binary variable indicating that entity \( i \) is closed at period \( t \); \( e_{r,i,j,p,t,s} \) is a binary variable that limits the amount of products that is transported from entity \( i \) to \( j \) using the transportation mode \( r \), at time \( t \), for each scenario \( s \).

The optimization problem involves determining the forward and reverse design of the network, while considering all the possible events characterized in the scenario tree. The goal of the stochastic model is to maximize the company profit taking into account, due to future events, the probable supply, demand and return rates \( (E_s, E_d \text{ and } E_r) \), while considering facility costs and costs due to raw material consumption, storage, transportation and emissions.

In stochastic approaches another important aspect to be considered is the suitable selection of objective functions. With that aim, three performance measures are considered in this paper: the expected profit and two types of measures that include risk criteria. The expected profit does not consider the effects of the variability of random outcomes. On the other hand, the two risk measures are suitable for stochastic problems and they can be included in mathematical models without changing the linear characteristic of the formulation. It is important to note that the incorporation of risk criteria in optimization formulations allows coping with real volatile markets, by trying to achieve the solutions less affected by parameters’ changes among those "immunized" against data uncertainty.
The two-stage mixed integer linear programming approach of the multi-product design and planning problem is presented in this section. Due to lack of space only the objective functions used in the model are presented in detail. Revenue and costs included in the objective function are listed. Model parameters used in this section are defined as follows: \( p_{cppt} \) represents the unit revenue of product \( p \) obtained by recycling materials, at time \( t \); \( f_{cci} \) is the cost for opening/ use of entity \( i \); \( f_{coi} \) is the cost for closing entity \( i \); \( c_{ij} \) is the unit transport cost of product \( p \) from entity \( i \) to entity \( j \), at time \( t \); \( e_{ij} \) is the estimated emission cost per unit of product \( p \) transported between entities \( i \) and \( j \), at time \( t \); \( d_{stij} \) is the distance between entities \( i \) and \( j \); \( u_{ipt} \) is the unit raw material purchasing cost of product \( p \) at suppliers \( i \), at time \( t \); \( s_{cpi} \) is the unit storage cost of product \( p \) at entity \( i \), at time \( t \).

The term (1) represents the revenue achieved by selling products to customers. It is computed for each scenario \( s \) considering all time periods \( T \), transportation modes \( TR \) and all products \( PR \) sent to customers \( (Ic) \) from warehouses \( (Iw) \) and distribution centers \( (Idc) \).

\[
RVNs: \quad \sum_{t \in T} \sum_{e \in (Iw \cup Idc)} \sum_{p \in PR} \sum_{e \in TR} pp_{pt} x_{pfrts} \tag{1}
\]

The term (2) denotes the revenue obtained by introducing recovered products/materials into the forward network. It is computed for each scenario \( s \) considering all time periods \( T \), transportation modes \( TR \) and all products \( PR \) that are returned from the reverse network to the forward network (\( A^{ft} \)).

\[
PRTs: \quad \sum_{t \in T} \sum_{d \in A^{ft}} \sum_{p \in PR} \sum_{t \in TR} pp_{pt} x_{pfrts} \tag{2}
\]

The term (3) symbolizes the cost for opening and closing facilities, which is independent of the scenarios. It is computed considering all time periods \( T \) and entities available in the network \( (I) \).

\[
OCF: \quad \sum_{t \in T} \sum_{i \in I} f_{cci} y_{it} + \sum_{t \in T} \sum_{i \in TR} f_{coi} w_{it} \tag{3}
\]

The term (4) denotes the transport and emissions costs of the forward and reverse chains, for each transportation mode \( TR \) and product \( PR \), considering all time periods \( T \). It is computed for each scenario \( s \) considering all the products transported between two entities \( (A) \).

\[
TECs: \quad \sum_{t \in T} \sum_{s \in A^{ft}} \sum_{p \in PR} \sum_{e \in TR} d_{stij} (c_{ij} + e_{ij}) x_{pfrts} \tag{4}
\]

The term (5) represents the purchasing cost of raw material transported from suppliers to plants (\( A^{pf} \)). It is computed for each scenario \( s \) considering all products \( PR \), transportation modes \( (TR) \) and time periods \( T \).

\[
PUCs: \quad \sum_{t \in T} \sum_{s \in A^{pf}} \sum_{p \in PR} \sum_{t \in TR} u_{ipt} x_{pfrts} \tag{5}
\]

The term (6) denotes the storage cost over all entities \( (I) \), products \( (PR) \) and time periods \( (T) \).

\[
STCs: \quad \sum_{t \in T} \sum_{s \in I} \sum_{p \in PR} s_{cpi} x_{pfrts} \tag{6}
\]

Terms \( RVN_s, PRT_s, TEC_s, PUC_s \) and \( STC_s \) depend on the scenario \( s \in SC \) and, therefore, depend on the occurrence probability \( (Pbs) \). It is worth noting that each scenario \( s \) is made up by a given sequence of events \( \Omega_s \) from the root node until a particular leaf node at the last time period. \( \Omega_s \) denotes the events \( es \in EEs, ed \in EEd \) and \( er \in EEr \) that occur for scenario \( s \) at time period \( t \).

### 3.1 Objective Function using Expected Revenue (ER)

Considering the expected profit of the CLSC, the performance measure is made up of the average revenue by selling new and recycled products, less the average costs related to raw material consumption, storage, transport, emissions (see term 7). The objective function \( OF_{ARS} \) is to maximize the revenue that depends on the scenarios probability (ARS) less the cost for opening and closing facilities, which is independent of the scenarios (see term 8).

\[
ARS: \quad \sum_{s \in SC} P_{bs} (RVN_s + PRT_s) - \sum_{s \in SC} P_{bs} (TEC_s + PUC_s + STC_s) \tag{7}
\]
3.2 Objective Function using Linear Measure of the Variability (LMV)

LMV is an absolute deviation, as proposed by Yu and Li (2000)[9], which is converted to a linear formulation by introducing non-negative deviational variables [10]. This measure is used in this work with the objective of avoiding the quadratic term that includes the traditional Markowitz mean-variance model. The LMV uses deviational variables subject to original problem constraints and additional soft constraints. The term (9) denotes the practical implementation of the variability measure. Constraint (10) is the additional soft constraint in order to ensure positive values of the difference inside the absolute function. The deviational variable \( d_v \) is equal to zero \( (d_v = 0) \) when \( (RVN_s + PRT_s - TEC_s - PUC_s - STC_s) \) is greater than \( ARS \). On the other hand, if \( ARS \) is greater than \( (RVN_s + PRT_s - TEC_s - PUC_s - STC_s) \), then \( d_v = ARS - (RVN_s + PRT_s - TEC_s - PUC_s - STC_s) \). Finally, the objective function \( OF_{LMV} \) is to maximize a combination of three terms, the expected revenue \( (ARS) \), the cost for opening and closing facilities \( (OCF) \) and the LMV measure of variability, subject to original problem constraints and constraint (10).

\[
LMV: \sum_{s \in SC} [Pb_s ((RVN_s + PRT_s - TEC_s - PUC_s - STC_s) - ARS) + 2d_v] \\
(9)
\\
(ARS) + d_v \geq 0 \forall s \in SC \\
(10)
\\
OF_{LMV}: \text{Max } ARS - OCF - LMV \\
(11)

3.3 Objective Function using Modified Linear Measure of the Variability (MLMV)

In this case, the objective function \( OF_{MLMV} \) is a variation of \( LMV \), where only the positive values of the deviational variables are considered. Thus, the term \( MLMV \) denoting the practical implementation of the variability measure is as follows:

\[
MLMV: \sum_{s \in SC} Pb_s d_v \\
(12)
\\
OF_{MLMV}: \text{Max } ARS - OCF - MLMV \\
(13)

The practical implementation of \( OF_{MLMV} \) includes also constraint (10). From the practical point of view, this objective function penalizes the set of scenarios associated to the occurrences of uncertain parameters that decrease the economic benefit of the company compared to \( ARS \). It is important to note that \( MLMV \) can be considered as a practical implementation of the mathematically well-behaved risk measure called value at risk (VaR), where the idea behind the metric in supply chain is to measure the performance of the network versus a given target or expectation.

4. NUMERICAL EXAMPLE

This section illustrates an example problem introduced by Paksoy et al., (2011)[8] for a CLSC with a super-structure composed of 3 suppliers \((s_1 \text{ to } s_3)\), 3 factories \((f_1 \text{ to } f_3)\), 1 warehouse \((w)\), 2 distribution centers \((dc_1 \text{ and } dc_2)\), 5 customers \((c_1 \text{ to } c_5)\), 2 collection centers \((cc_1 \text{ and } cc_2)\), 2 dismantlers \((d_1 \text{ and } d_2)\), 1 repairing center \((rc)\), 1 final disposal \((fd)\), and 2 decomposition centers \((dp_1 \text{ and } dp_2)\). In order to illustrate the application of the two-stage multi-product model, the reference problem was modified including possible states of the uncertain parameters and their probabilities. The design and planning of the mentioned super-structure must be optimized in order to improve the firm’s profit.

The planning horizon is equal to ten years, which is subdivided into two 5-year periods. Products in the network are aggregated to form 3 groups: products Fully recyclable \((Frcy)\) (with a recycle rate of 100%), Partially recyclable \((Prcy)\) (with a recycle rate of 50%) and Non-reusable \((Nrcy)\) (with a recycle rate of 0%). The product flow through the reverse network entities is described by \( \beta = 0.4, \chi = 0.7, \epsilon = 0.7, \delta = \{(\delta_{Frcy}, \delta_{Prcy}, \delta_{Nrcy})=(1,0.7,0)\} \). A transport system with three types of trucks \((tp_1, tp_2 \text{ and } tp_3)\) is assumed. Each transportation mode has specific unit CO2 emissions and transport costs. In this case, three possible levels for the uncertainty of raw material supply, demand and return rates are considered. Table 1 shows the states, and their probabilities, for each uncertain parameter. It is worth noting that the return rates depend on the product group. For example, \( \alpha \) for state \( er_1 \) is equal to \( \{(\alpha_{Frcy}, \alpha_{Prcy}, \alpha_{Nrcy})=(1,0.7,0.3)\} \).
Table 1 – Stochastic states of supply, demand and return quality

<table>
<thead>
<tr>
<th>State</th>
<th>Supply</th>
<th>Demand</th>
<th>Return Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>$es_1/0.3$</td>
<td>$ed_1/0.1$</td>
<td>$er_1/0.5$</td>
</tr>
<tr>
<td>Middle</td>
<td>$es_2/0.5$</td>
<td>$ed_2/0.6$</td>
<td>$er_2/0.3$</td>
</tr>
<tr>
<td>High</td>
<td>$es_3/0.2$</td>
<td>$ed_3/0.3$</td>
<td>$er_3/0.2$</td>
</tr>
</tbody>
</table>

4. RESULTS

To illustrate the validity of the proposed two-stage formulation, the approach was implemented in GAMS 23.6.3, and instances of the example presented in the previous section were solved with CPLEX 12.2, on a HP Z800 workstation with Intel Xeon x5650 2.66 GHz and 16 GB RAM memory for a 0.01% gap tolerance. In addition, the advantages of the proposed stochastic programming approach using different performance measures introduced above (OF_{ER}, OF_{LMV} and OF_{MLMV}) are evaluated.

Because for each parameter its variations are represented by three possible levels and the raw material supply, demand and return rates do not change during the second time period, the formulation is based on a two-layered tree with 27 scenarios. Table 1 reports the results obtained solving the formulation with the objective functions: OF_{ER}, OF_{LMV} and OF_{MLMV}. Thus, it shows results for the average profit and two types of measures that include risk criteria. In all cases, the full scenario tree with 27 scenarios and 54 tree nodes (due to two time periods being considered) was used.

Table 2 – Results for solving the stochastic approach with different objective functions

<table>
<thead>
<tr>
<th>Cases</th>
<th>Scenarios</th>
<th>Tree Nodes</th>
<th>OF_{ER}</th>
<th>OF_{LMV}</th>
<th>OF_{MLMV}</th>
<th>Time [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>OF_{ER}</td>
<td>27</td>
<td>54</td>
<td>1052722468</td>
<td>1067021914</td>
<td>65713805</td>
<td>32856903</td>
</tr>
<tr>
<td>OF_{LMV}</td>
<td>27</td>
<td>54</td>
<td>990609741</td>
<td>1053260457</td>
<td>48471320</td>
<td>24235660</td>
</tr>
<tr>
<td>OF_{MLMV}</td>
<td>27</td>
<td>54</td>
<td>1021868018</td>
<td>1068863171</td>
<td>65511434</td>
<td>32755717</td>
</tr>
</tbody>
</table>

All values are expressed in currency units [c.u.].

As it can be seen from the results in Table 2, the use of OF_{LMV} is extremely computationally intensive, while the other two performance measures require a reasonably acceptable computational effort. The use of OF_{MLMV} leads to a solution with average profit (ER) greater than the ones obtained using OF_{ER} and OF_{LMV}. In addition, LMV and MLMV values obtained with OF_{MLMV} are lower than those achieved using OF_{ER} but higher than those found using OF_{LMV}. It is worth noting that OF_{MLMV} presents an acceptable tradeoff between the average profit and the variability measures.

Table 3 presents detailed information about the solutions obtained with different objective functions. The table shows the cost for opening and closing facilities, the average of the different types of costs (transport, emissions, purchasing and storage) and the average revenue due to the amount of products delivered to customers and returned to the forward network.

Table 3 – Detailed information about the solutions obtained in instances ER, LMV and MLMV

<table>
<thead>
<tr>
<th>Cases</th>
<th>Facility</th>
<th>Transport</th>
<th>Emissions</th>
<th>Purchasing</th>
<th>Storage</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>OF_{ER}</td>
<td>14299446</td>
<td>111809692</td>
<td>43717150</td>
<td>1114893</td>
<td>64245</td>
<td>1221471544</td>
</tr>
<tr>
<td>OF_{LMV}</td>
<td>14179396</td>
<td>113317057</td>
<td>43805247</td>
<td>1110467</td>
<td>69544</td>
<td>1209455656</td>
</tr>
<tr>
<td>OF_{MLMV}</td>
<td>14239436</td>
<td>111994987</td>
<td>43423930</td>
<td>1114893</td>
<td>64089</td>
<td>1223246176</td>
</tr>
</tbody>
</table>

All values are expressed in currency units [c.u.].

As it can be seen in Table 3, the use of OF_{LMV} leads to a solution with facility and purchasing costs, and revenues smaller than the ones of the solution obtained with OF_{MLMV} and OF_{ER}. Nevertheless, transport, emissions and storage costs of OF_{LMV} are greater than the values achieved using OF_{MLMV} and OF_{ER}. In addition, the most significant relative difference between the three solutions found is presented in the cost of storage. The costs and benefits of the solutions obtained using the objective function OF_{MLMV} are similar to that obtained using OF_{ER} (with differences smaller than 1.8%). However, the network structures obtained using OF_{MLMV} and OF_{ER} are different.
Table 4 shows the network structures for the different solutions and it can be observed that changes are restricted to the reverse network (collection centers, dismantlers and decomposition centers). By comparing the structure obtained in case NSLMV with the one achieved with NSMLMV, it can be easily observed the differences in these entities. The network structure obtained for the latter is able to address a greater amount of product due to the presence in the reverse chain of the dismantler 1 (d1), which has higher processing capacity than dismantler 2 (d2). By comparing the structures obtained in cases NSLMV and NSMLMV with the one achieved with NSER, it can be seen that the NSER uses in a more intensive way both dismantlers (d1 in time periods t1 and t2, and d2 in time period t1).

| Structure/Entity | s1 | s2 | s3 | f1 | f2 | f3 | w | dc1 | dc2 | cc1 | cc2 | rc | d1 | d2 | dp1 | dp2 | fd |
|------------------|----|----|----|----|----|----|----|-----|-----|-----|-----|----|----|----|-----|-----|
| NSER             | *  | *  | *  | *  | *  | *  | *  | *   | *   | *   | *   | *  | *  | *  | *   | *   |
|                  | t1 |     |    |    |    |    |    |      |      |      |      |    |    |    |      |      |
|                  | t2 |     |    |    | *  | *  | *  |      |      |      |      |    |    |    |      |      |
| NSLMV            | *  | *  | *  | *  | *  | *  | *  | *   | *   | *   | *   | *  | *  | *  | *   | *   |
|                  | t1 |     |    |    |    |    |    |      |      |      |      |    |    |    |      |      |
|                  | t2 | *  | *  | *  |    |    |    |      |      |      |      |    |    |    |      |      |
| NSMLMV           | *  | *  | *  | *  | *  | *  | *  | *   | *   | *   | *   | *  | *  | *  | *   | *   |
|                  | t1 |     |    |    | *  | *  | *  |      |      |      |      |    |    |    |      |      |
|                  | t2 | *  | *  | *  |    |    |    |      |      |      |      |    |    |    |      |      |

*entity included in the network

Table 5 shows the behavior of the network structures shown in Table 4, when different scenarios are considered.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Network Structure</th>
<th>OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sc1</td>
<td>NSER</td>
<td>1000522596</td>
</tr>
<tr>
<td>Sc1</td>
<td>NSLMV</td>
<td>1001389617</td>
</tr>
<tr>
<td>Sc1</td>
<td>NSMLMV</td>
<td>1001562647</td>
</tr>
<tr>
<td>Sc2</td>
<td>NSER</td>
<td>1021317748</td>
</tr>
<tr>
<td>Sc2</td>
<td>NSLMV</td>
<td>1022921278</td>
</tr>
<tr>
<td>Sc2</td>
<td>NSMLMV</td>
<td>1023021609</td>
</tr>
<tr>
<td>Sc3</td>
<td>NSER</td>
<td>1128168907</td>
</tr>
<tr>
<td>Sc3</td>
<td>NSLMV</td>
<td>1129593415</td>
</tr>
<tr>
<td>Sc3</td>
<td>NSMLMV</td>
<td>1129736243</td>
</tr>
</tbody>
</table>

Thus, Table 5 shows the results obtained by fixing the network structure and considering three different scenarios: Sc1 takes into account that the three uncertain parameters adopt their lowest states (es1, ed1, er1), Sc2 the middle states (es2, ed2, er2) and, finally, Sc3 the highest states (es3, ed3, er3). As it can be seen in the table, NSMLMV obtains the greatest revenues for the three scenarios. In addition, NSER, which was obtained without considering any measure of the parameter variability, exhibits the worst performance.

5. CONCLUSIONS

In this paper a two-stage stochastic model is introduced to deal with the design and planning problem of multi-product closed-loop supply chains with three uncertain parameters. The mathematical formulation aims at achieving optimal solutions while avoiding that alterations on uncertain levels of raw material, customer demands and return rates produce relevant modifications in the objective function value. Thus, in the proposed stochastic approaches three performance measures are evaluated in order to make a suitable selection of the objective function. To show the application of the approach, an example proposed in the literature is examined. The results show the relevance of considering the stochastic approach with
performance measures that include risk criteria, and, furthermore, the computational benefit of using the Modified Linear Measure of the Variability, due to the reasonable computational effort to solve the problem. A scenario analysis of the CLSC is further carried out to highlight the benefits of using the MLMV risk criteria to derive managerial insights into its design and planning.

As future work, a multi-stage stochastic model to deal with the temporal changes of the uncertain parameters during the planning horizon is to be developed. In addition, a specialized solution method is to be investigated to further increase the efficiency of the solution space.

7. ACKNOWLEDGMENTS

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8. REFERENCES

A MODEL FOR THROUGHPUT AND ENERGY RELATED PERFORMANCE CALCULATIONS OF SBS/RS

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Abstract

In this paper a model for throughput and energy related performance calculations of a shuttle based storage and retrieval system (SBS/RS), is presented. SBS/RS is relatively a new technology in automated storage and retrieval system. Since it is important to design SBS/RSs right the first time due to the relative inflexibility of the physical layout and the equipment, we provide a model for performance calculation of these systems. The performance of the system is considered as throughput capacity and the amount of energy consumption.

Keywords: automated warehouses, shuttle based storage and retrieval systems, throughput capacity, energy consumption, performance analysis

1. INTRODUCTION

Warehouses are critical for supply chains. To be able to increase space utilization in a warehouse, managers prefer a high-rise storage area with a relatively small foot-print that storage locations on racks, which are accessible via narrow aisles. Having numerous numbers of tiers in storage area creates necessity for fast and efficient storage and retrieval system to store/retrieve loads to/from storage locations to increase the throughput capacity. With advances in technology, new automated material handling technologies providing greater responsiveness and additional flexibility in fulfilling orders have been developed. A major segment in the material handling industry is the Automated Storage and Retrieval System (AS/RS). There are primarily two types of AS/RSs – traditional, Crane-Based Automated Storage and Retrieval System (CBAS/RSs) and the Autonomous Vehicle Storage and Retrieval Systems (AVS/RSs).

CBAS/RS are widely used in warehouses throughout the world. It is usually consist of conveyors, racks and automated Storage/Retrieval (S/R) devices (cranes) [22]. The cranes are fully automated and can travel in narrow aisles between the racks to pick up and drop off loads.

Advances in "Autonomous Vehicle" (AV) hardware technologies have helped manufacturers of material handling systems pursue the use of AVs instead of fixed-path cranes in Unit-Load (UL) storage and retrieval. AVS/RS, a relatively new technology for automated UL storage systems, has been implemented at scores of facilities, primarily in Europe [17]. Due to the ability of accessing any storage positions in the storage racks and flexibility in changing the number of AVs, this system has advantages compared to traditional CBAS/RS. Based on the vehicle assignment policy to storage tiers, there can be two main configurations: AVS/RS with a tier-to-tier configuration; AVS/RS with a tier-captive configuration [19]. Both configurations may also be adjusted by including aisle-captive or aisle-to-aisle assignment policies.

Shuttle Based Storage and Retrieval System (SBS/RS) is relatively a new technology in AVS/RS and usually works with aisle and tier captive shuttles. This new technology is mostly used for mini-load warehouse systems [1, 14, 15]. The vertical movement of AVs is facilitated by lifts mounted along the periphery of the storage racks. In aisle-to-aisle AVS/RS, in the horizontal movement, vehicles follow rectilinear travel pattern.

It is important to design SBS/RSs right the first time due to the relative inflexibility of the physical layout and the equipment. To be able to evaluate the performance of these designs an accurate, fast working model is required. By this purpose, in this paper, models for throughput and energy related performance calculations of SBS/RS are presented. The performance of the system is considered in terms of average cycle time (throughput rate) and the amount of energy consumption of the system.
2. LITERATURE REVIEW

AVS/RS is first studied by Malmborg [17]. Malmborg [18] proposes a state equation model for predicting the proportion of dual command (DC) cycles in AVS/RSs. Although there are some limitations in the proposed model, it provides a useful tool for estimating DC cycles in AVS/RS. Fukunari and Malmborg [9, 10] develop an efficient cycle time model for AVS/RS and compare their performance with CBAS/RS. The model is based on an iterative computational scheme considering random storage assumptions and queuing model approximations. This model also improves upon earlier models by scaling efficiently for large problems. The procedure is shown using realistically sized problems. Kuo et al. [11, 12] developed an efficient cycle time model for AVS/RS estimating resource utilization. They solved 12 different scenarios to show the performance of the model. Although the model shows some substantial errors, the model can provide an accuracy level for estimates of vehicle utilization and system cost. Zhang et al. [23] studied variance based approximation for waiting times in AVS/RS. They modeled the system using a series of queuing approximations, by dynamically selecting between three alternative queuing approximations based on the squared coefficient of variation (SCV) of transaction inter-arrival times. Recently, Ekren et al. [4], Ekren [2] and Ekren and Heragu [8] have studied simulation based performance evaluation of AVS/RS. They study near optimum rack configuration design under pre-defined scenarios of number of vehicles and lifts in the system using simulation based regression analysis [7] and implement a design of experiments for an AVS/RS to identify factors affecting its performance [7]. Roy et al. [21] proposed a semi-open queuing network (SOQN) model to evaluate design trade-offs in a single tier of an AVS/RS. Ekren et al. [5, 6] also study SOQN to model an AVS/RS. They use their pre-proposed extended algorithm [3] to calculate the performance measure of the system. The most related paper to the studied system is completed by Carlo and Vis [1]. They study a type of SBS/RS where there are two non-passing lifting systems mounted along the rack. They focus on scheduling problem where two (piece-wise linear) functions are introduced to evaluate candidate solutions. Marchet et al. [19] study main design trade-offs for AVS/RS using simulation. They complete their study for several warehouse design scenarios for two types of AVS/RS configurations: tier captive and tier-to-tier vehicles. Lerher et al. [13, 15] study multi-objective optimization for automated warehouses. For the optimization of decision variables in objective functions, the method with genetic algorithms has been used. Recently, Lerher [16] and Lerher et al. [14] have studied energy regeneration and energy efficiency models for SBS/RS. The proposed models enable reduction of energy consumption and consequently the CO2 emission, which is vital from economic and environmental point of view. It is sincerely believed that the energy and environment aspect will indubitably bring changes into planning of warehouses and will mean great challenge for those, who are engaged in the planning process.

3. MODEL FOR THROUGHPUT AND ENERGY RELATED PERFORMANCE CALCULATIONS OF SBS/RS

According to global trends, there is a necessity to take into account the energy consumption along with the usually applied objectives (minimum travel time and maximum throughput). In the following sections, calculations for the throughput capacity and the amount of energy consumption as performance measures for the SBS/RS, will be presented.

3.1 Throughput performance of the elevator

The elevator can work on a Single Command Cycle (SCC), which means that only one tote can be handled at a time. More advanced is Dual Command Cycle (DCC), by which two totes are handled in a cycle (Fig. 1).

Single command average cycle time calculations

In the case of SCC, the elevator carries the lifting table with a tote to tier \( j \), unloads the tote and moves back to the I/O location. The same sequence can also be performed in reverse order [20].

Single command average cycle time \( T(\text{SC})_{\text{in}} \) is calculated by (1):

\[
T(\text{SC})_{\text{in}} = 2 \cdot t_i + 2 \cdot t_{\text{io},j}
\]

\[
T(\text{SC})_{\text{in}} = 2 \cdot t_i + \frac{2 \cdot v_y \cdot h}{v_r} + \frac{h}{v_r} (m + 1)
\]  

(1)
Dual command average cycle time calculations

In the case of DCC, the elevator moves the lifting table with the tote to tier $i$, unloads the tote and moves further to the tier $j$, where the tote is retrieved. After loading the tote at tier $j$, the elevator moves the lifting table back to the I/O location [20].

Average dual command cycle time $T_{\text{DC}}^{\text{lift}}$ is calculated by (2):

$$T_{\text{DC}}^{\text{lift}} = 4 \cdot t_i + 2 \cdot t_{\text{vO}_{ij}} + 2 \cdot t_{l_{ij}}$$

(2)

Throughput performance calculations

By considering (2) the throughput performance of the DCC per hour is calculated by (3):

$$\lambda_{\text{DC}}^{\text{lift}} = \frac{3600}{T_{\text{DC}}^{\text{lift}}} \cdot k \quad (k = 2)$$

(3)

where $k$ is 2, due to the DCC.

3.2 Throughput performance of the shuttle carrier

A shuttle carrier can receive one tote at a time and can operate on a single or dual command cycles (FEM Section IX, 2001).

Single command average cycle time calculations

The operation of SCC encompasses either a storage or a retrieval process. After completing a given storage or retrieval request at point $P_i(x_i)$, the shuttle carrier returns directly to the I/O tier $j$. According to the Fig. 2, a single storage request is performed at point $P_1$ and a single retrieval request is performed at point $P_2$. In the case of SCC, the shuttle carrier operates only one tote.

Single command average cycle time $T_{\text{SC}}^{\text{shut}}$ is calculated by (4):

$$T_{\text{SC}}^{\text{shut}} = 2 \cdot t_i + \frac{t_{\text{vO}_{1i}P_1} + t_{P_2} + t_{\text{vO}_{2i}}}{2}$$

(4)
Dual command average cycle time calculations

The operation of DCC considers storage and retrieval processes at a time. Recall that in DCC, the shuttle carrier travels to two storage locations between successive returns to the I/O

\[ T(\text{DC})_{\text{shut}} = 4 \cdot t_{1} + t_{\text{I/O tier}_j, P_{1}} + t_{P_1, P_2} + t_{\text{I/O tier}_j} \]  

Throughput performance calculations

According to (5) the throughput performance of the DCC is calculated by (6):

\[ \lambda(\text{DC})_{\text{shut}} = \frac{3600}{T(\text{DC})_{\text{shut}}} \cdot k \quad (k = 2), \]

where \( k \) is 2, due to the DCC.

3.3 Amount of energy consumption in SBS/RS

Required engine power for travelling of the shuttle carrier

When the shuttle-carrier travels with constant velocity only \( (a_x = 0) \), the traction force \( F_{Tv} \) on the rear driving wheel equals (7):

\[ F_{Tv} = G \cdot k_r \]

It can be noticed that the traction force \( F_{Tv} \) on the rear driving wheel is overcoming the rolling resistance \( F_R \) only. The size of the traction force \( F_{Tv} \) depends on the: (i) mass of the shuttle-carrier and the tote and (ii) rolling resistance coefficient \( k_r \).

Required engine power \( P_{Tv} \) of shuttle-carrier in case of travelling with constant velocity \( (a_x = 0) \), is calculated by (8):

\[ P_{Tv} = \frac{F_{Tv} \cdot v_x}{1000 \cdot \eta} \quad [\text{kW}] \]

When shuttle-carrier accelerates \( (a_x \neq 0) \), the traction force \( F_{Ta} \) on the rear driving wheel equals (9):

\[ F_{Ta} = G \cdot k_r + \frac{G}{g} \cdot a_x \cdot k_r \]

It can be noticed that the traction force \( F_{Tv} \) on the rear driving wheel is overcoming the rolling resistance \( F_R \) and the inertial resistance \( F_i \). The size of the traction force \( F_{Tv} \) depends on the: (i) mass of the shuttle-carrier with the tote, (ii) rolling resistance coefficient \( k_r \), (iii) size of acceleration \( a_x \), and (iv) factor \( k_r \) that takes into account the resistance of rotating masses with variable vehicle speed.
Required engine power $P_{T_a}$ of the shuttle-carrier in case of accelerating ($a_{x}^+ \neq 0$), is calculated by (10):

$$F_{T_a} = G \cdot k_{x} + \frac{G}{g} \cdot a_{x}^+ \cdot k_{y}$$

(10)

**Required engine power for the hoisting of elevators lifting table**

When the lifting table is hoisting with constant velocity only ($a_{y}^+ = 0$), the traction force $F_{T_v}$ equals (11):

$$F_{T_v} = G$$

(11)

It can be noticed that the traction force $F_{T_v}$ is overcoming the force of gravity $G$ only. The size of the traction force $F_{T_v}$ depends on the mass of the lifting table with tote.

Required engine power $P_{T_v}$ of the lifting table in case of hoisting with the constant velocity ($a_{y}^+ = 0$), is calculated by (12):

$$P_{T_v} = \frac{F_{T_v} \cdot v_{y}}{1000 \cdot \eta} [kW]$$

(12)

When the lifting table accelerates ($a_{y}^+ \neq 0$), the traction force $F_{T_a}$ is calculated by (13):

$$F_{T_a} = G + \frac{G}{g} \cdot a_{y}^+ \cdot k_{y}$$

(13)

It can be noticed that the traction force $F_{T_a}$ is overcoming the force of gravity $G$ and the inertial resistance $F_{ir}$. The size of the traction force $F_{T_a}$ depends on the: (i) mass of the lifting table along with the tote, (ii) size of acceleration $a_{y}^+$ and (iii) factor $k_{ir}$ that take into account the resistance of rotating masses with variable vehicle speed.

Required engine power $P_{T_a}$ of the lifting table in case of hoisting with non-constant velocity ($a_{y}^+ \neq 0$), is calculated by (14):

$$P_{T_a} = \frac{F_{T_a} \cdot v_{y}}{1000 \cdot \eta} [kW]$$

(14)

### 3.4 Calculation of amount of energy consumption

Amount of energy consumption $- E_{CON} -$ counted on a yearly basis depends on the engine power of the lift/shuttle carrier $P$, efficiency of the lift/shuttle carrier $\eta$, number of working hours in a shift $T_{shift}$, number of working days in a week $n_{wd}$, number of weeks $n_{weeks}$, number of lifting tables/shuttle carrier $n$, number of aisles $A$ and is calculated by (15):

$$E_{CON} = P \cdot \eta \cdot T_{shift} \cdot n_{wd} \cdot n_{weeks} \cdot n \cdot R \left[ \frac{kWh}{\text{year}} \right]$$

(15)

### 4. SBS/RS UNDER STUDY

In this section, main input data for the analysis are provided and discussed. Stock keeping unit represents a tote (plastic container) filled with items with the dimensions: length $l_{tote} = 0.6$ m, width $w_{tote} = 0.4$ m and height $h_{tote} = 0.24$ m. With regard to the tote, the storage place has the following dimensions: length (depth) of the storage rack $l_{COM} = 0.6$ m, width of the column $w_{COM} = 0.5$ m and height of the tier $h_{COM} = 0.35$ m. Dimensions of the SBS/RS storage rack ($L_{SR}$ and $H_{SR}$) depends on the number of columns $C$ in the horizontal direction and number of tiers $T$ in the vertical direction, respectively.

As it will be seen in Table 1, nine SBS/RS configurations were analyzed based on three values of tiers $T$ ($T = 10, 15$ and $20$) and three values of aisles $A$ ($A = 3, 6$ and $9$). Total number of storage positions $- Q -$ is assumed to be approximately 10,000 storage locations [19].
Table 1 – SBS/RS configurations

<table>
<thead>
<tr>
<th>SBS/RS configuration (RC)</th>
<th>Number of tiers (T)</th>
<th>Number of aisles (A)</th>
<th>Number of columns (C)</th>
<th>Length of the SR (L&lt;sub&gt;SR&lt;/sub&gt; in m)</th>
<th>Height of the SR (H&lt;sub&gt;SR&lt;/sub&gt; in m)</th>
<th>Warehouse volume (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>3</td>
<td>167</td>
<td>83.5</td>
<td>3.5</td>
<td>10020</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>6</td>
<td>84</td>
<td>42</td>
<td>3.5</td>
<td>10080</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>9</td>
<td>56</td>
<td>28</td>
<td>3.5</td>
<td>10080</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>3</td>
<td>112</td>
<td>56</td>
<td>5.25</td>
<td>10080</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>6</td>
<td>56</td>
<td>28</td>
<td>5.25</td>
<td>10080</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>9</td>
<td>38</td>
<td>19</td>
<td>5.25</td>
<td>10260</td>
</tr>
<tr>
<td>7</td>
<td>20</td>
<td>3</td>
<td>84</td>
<td>42</td>
<td>7</td>
<td>10080</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>6</td>
<td>42</td>
<td>21</td>
<td>7</td>
<td>10080</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>9</td>
<td>28</td>
<td>14</td>
<td>7</td>
<td>10080</td>
</tr>
</tbody>
</table>

Note: SBS/RS configurations are selected according to the references of material handling equipment producers and practical experiences of the authors.

Since the throughput capacity $\lambda$ and consequently the energy consumption $E_{CON}$ greatly depends on the velocity characteristics of the elevators and the shuttle carrier, selected velocity profile $v_p$ was used in our analysis (see Table 2).

Table 2 – Velocity scenario of the shuttle carrier and the elevators lifting table

<table>
<thead>
<tr>
<th>Velocity profile</th>
<th>Shuttle carrier travelling in the horizontal direction</th>
<th>Lifting table movement in the vertical direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_p$ (m/s)</td>
<td>$a_x$ (m/s$^2$)</td>
<td>$a_y$ (m/s$^2$)</td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note: Velocity scenario $v_p$ is selected according to the references of material handling equipment producers and practical experiences of the authors.

Total mass of the lifting table, shuttle carrier and the tote are presented in Table 3.

Table 3 – Total mass of the lifting table, the shuttle carrier and the container

<table>
<thead>
<tr>
<th>mass of the full tote (kg)</th>
<th>mass of the lifting table (kg)</th>
<th>mass of the shuttle carrier (kg)</th>
<th>total mass of the shuttle carrier (kg)</th>
<th>total mass of the lifting table (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>60</td>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
</tbody>
</table>

Note: The proposed masses are approximately specified according to the knowledge in material handling and might differ from the actual systems installed in practice.

Other data that are used in the analyses are presented in Table 4.

Table 4 – Other data used in the analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit of measure</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{shuttle}$</td>
<td>sec</td>
<td>3</td>
</tr>
<tr>
<td>$t_{shift}$</td>
<td>sec</td>
<td>1.5</td>
</tr>
<tr>
<td>$g$</td>
<td>m/s$^2$</td>
<td>10</td>
</tr>
<tr>
<td>$k_{ir}$</td>
<td>/</td>
<td>1.15</td>
</tr>
<tr>
<td>$k_r$</td>
<td>/</td>
<td>0.01</td>
</tr>
<tr>
<td>$T_{shift}$</td>
<td>hours</td>
<td>16</td>
</tr>
<tr>
<td>$n_{wd}$</td>
<td>days</td>
<td>5</td>
</tr>
<tr>
<td>$n_{weeks}$</td>
<td>weeks</td>
<td>50</td>
</tr>
</tbody>
</table>
5. RESULTS

5.1 Throughput performance of the SBS/RS

Table 5 summarizes dual command average cycle time of lifts $T(DC)_{lift}$ and shuttle carriers $T(DC)_{shut}$, the throughput performance of lifts $\lambda(DC)_{lift}$ and shuttle carriers $\lambda(DC)_{shut}$, the efficiency of the lift $\eta_{lift}$ and the shuttle carrier $\eta_{shut}$ and the throughput performance $\lambda$ of the whole SBS/RS. Because of the SBS/RS is composed of lift and the tier-captive shuttle carriers that are working independently from each other, the possible bottleneck is required to be found for calculating the whole SBS/RS performance.

<table>
<thead>
<tr>
<th>$vp$</th>
<th>$RC_i$</th>
<th>$T(DC)_{shut}$ (sec.)</th>
<th>$T(DC)_{lift}$ (sec.)</th>
<th>$\lambda(DC)_{shut}$ (totes/h)</th>
<th>$\lambda(DC)_{lift}$ (totes/h)</th>
<th>$\eta_{lift}$</th>
<th>$\eta_{shut}$</th>
<th>$\tau$</th>
<th>$\lambda(DC)_{aisle}$ (totes/h)</th>
<th>$\lambda(DC)_{SBS/RS}$ (totes/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>89.22</td>
<td>13.89</td>
<td>807</td>
<td>1037</td>
<td>0.78</td>
<td>1.00</td>
<td>shutt.</td>
<td>807</td>
<td>2421</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>52.33</td>
<td>13.89</td>
<td>1376</td>
<td>1037</td>
<td>1.00</td>
<td>0.75</td>
<td>lift</td>
<td>1037</td>
<td>6222</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>39.89</td>
<td>13.89</td>
<td>1805</td>
<td>1037</td>
<td>1.00</td>
<td>0.57</td>
<td>lift</td>
<td>1037</td>
<td>9333</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>64.78</td>
<td>15.83</td>
<td>1667</td>
<td>909</td>
<td>1.00</td>
<td>0.55</td>
<td>lift</td>
<td>909</td>
<td>2727</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>39.89</td>
<td>15.83</td>
<td>2708</td>
<td>909</td>
<td>1.00</td>
<td>0.34</td>
<td>lift</td>
<td>909</td>
<td>5454</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>31.89</td>
<td>15.83</td>
<td>3387</td>
<td>909</td>
<td>1.00</td>
<td>0.27</td>
<td>lift</td>
<td>909</td>
<td>8181</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>52.33</td>
<td>17.78</td>
<td>2752</td>
<td>810</td>
<td>1.00</td>
<td>0.29</td>
<td>lift</td>
<td>810</td>
<td>2430</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>33.67</td>
<td>17.78</td>
<td>4277</td>
<td>810</td>
<td>1.00</td>
<td>0.19</td>
<td>lift</td>
<td>810</td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>27.44</td>
<td>17.78</td>
<td>5247</td>
<td>810</td>
<td>1.00</td>
<td>0.15</td>
<td>lift</td>
<td>810</td>
<td>7290</td>
<td></td>
</tr>
</tbody>
</table>

$RC_i$ column shows nine rack configurations for the SBS/RS defined in Table 1. Recall that, the dual command average travel time of the lift $T(DC)_{lift}$ and the shuttle carrier $T(DC)_{shut}$ are calculated by (2) and by (5), respectively. The throughput performance of the lift $\lambda(DC)_{lift}$ and the shuttle carrier $\lambda(DC)_{shut}$ are calculated by using (3) and (6), respectively.

The efficiency $\eta$ of the lift and the shuttle carrier is calculated by (16):

$$\eta = \frac{\min\{\lambda(DC)_{shut}, \lambda(DC)_{lift}\}}{\max\{\lambda(DC)_{shut}, \lambda(DC)_{lift}\}}$$  \hspace{1cm} (16)

The expected bottleneck is found by $\tau$ calculation as in (17):

$$\tau = \max\{\lambda(DC)_{shut}, \lambda(DC)_{lift}\}$$  \hspace{1cm} (17)

The throughput capacity $\lambda(DC)_{aisle}$ of SBS/RS in one aisle equals (18):

$$\lambda(DC)_{aisle} = \min\{\lambda(DC)_{shut}, \lambda(DC)_{lift}\}$$  \hspace{1cm} (18)

The whole SBS/RS system performance $\lambda(DC)_{SBS/RS}$ is calculated by (19):

$$\lambda(DC)_{SBS/RS} = A \cdot \lambda(DC)_{aisle}$$  \hspace{1cm} (19)

According to the results presented in Table 5, the throughput performance of the SBS/RS is influenced by the number of tiers $T$, number of aisles $A$, number of columns $C$, the velocity of the elevators lifting table ($v_y, a_y$) and the velocity of the shuttle carriers ($v_x, a_x$). The system performance mainly depends of the performance of the elevators feeding the storage racks. Since a shuttle carrier can handle more work than an elevator, the assumption of tier-captive shuttles can be released. In more advanced systems, a shuttle carrier can by using a special elevator at the back of the storage rack, operate in more tiers than a single one. Since the throughput performance of a SBS/RS is determined by the elevator, the elevator should receive the most of the attention when designing SBS/RS.
5.2 Energy consumption of the SBS/RS

Tables 6 and 7 summarize amount of energy consumption – $E_{\text{CON}}$ – for shuttle carriers and lifts respectively. They also provide the number of dual command cycles of lifts and shuttle carriers $n_{\text{DC}}$, required engine power – $P$ – for the lift and the shuttle carrier, efficiency of the lift/shuttle carrier $\eta$, number of working hours in a shift $T_{\text{shift}}$, number of working days in a week $n_{\text{wd}}$, number of weeks $n_{\text{weeks}}$, number of lifting tables/shuttle carriers $n$, number of aisles $A$ and throughput capacity of lifts and shuttle carriers $\lambda$.

Table 6 – Amount of energy consumption distribution of shuttle carriers

<table>
<thead>
<tr>
<th>vp</th>
<th>RCi</th>
<th>$n_{\text{DC}}$</th>
<th>$\eta_{\text{shut}}$</th>
<th>$P$ (kW)</th>
<th>$T_{\text{shift}} \cdot n_{\text{wd}} \cdot n_{\text{weeks}}$</th>
<th>No. of shuttles</th>
<th>$A$ (/)</th>
<th>$E_{\text{CON}}$ (kWh/y)</th>
<th>$\lambda$(DC)$_{\text{shut}}$ (totes/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>1.00</td>
<td>0.18</td>
<td>4000</td>
<td>10</td>
<td>3</td>
<td>21600</td>
<td>807</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>69</td>
<td>0.75</td>
<td>0.18</td>
<td>4000</td>
<td>10</td>
<td>6</td>
<td>32400</td>
<td>1376</td>
<td></td>
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<td>9</td>
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<td>5247</td>
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</table>

Table 7 – Amount of energy consumption distribution of lifts

<table>
<thead>
<tr>
<th>vp</th>
<th>RCi</th>
<th>$n_{\text{DC}}$</th>
<th>$\eta_{\text{lift}}$</th>
<th>$P$ (kW)</th>
<th>$T_{\text{shift}} \cdot n_{\text{wd}} \cdot n_{\text{weeks}}$</th>
<th>No. of lifting tables</th>
<th>$A$ (/)</th>
<th>$E_{\text{CON}}$ (kWh/y)</th>
<th>$\lambda$(DC)$_{\text{lift}}$ (totes/h)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<td>0.85</td>
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<td>2</td>
<td>259</td>
<td>1.00</td>
<td>1.56</td>
<td>4000</td>
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<td>6</td>
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<td>1.56</td>
<td>4000</td>
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<td>112320</td>
<td>810</td>
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</tr>
</tbody>
</table>

The amount of energy consumption is also influenced by the number of tiers $T$, number of aisles $A$, number of columns $C$, the velocity of the elevators lifting table ($v_y$, $a_y$) and the velocity of the shuttle carriers ($v_x$, $a_x$). Generally, the highest energy consumption $E_{\text{CON}}$ is achieved with the elevator and the shuttle carrier having the fastest drives. It can be concluded that the significant difference of energy consumption – $E_{\text{CON}}$ – in the present case originates as a result of changing the horizontal velocity $v_x$.

6. CONCLUSIONS

In this paper, a model for calculating the system performance of a SBS/RS is presented. The proposed model consists of calculations for the throughput capacity of the elevator and the shuttle carriers and the calculations for the energy consumption of the system.

SBS/RS are usually used by companies dealing with large number of small sized orders requiring to be processed in a relatively short time period. In practice, there is an approximation that this system could reach up to 1000 containers per hour. This study fills the gap in the literature where there is no conceptual model calculating the system performance and the energy consumption of the system.
The proposed model presents an analytical travel time model calculating the system performance of the elevator and the shuttle carrier. Along with the system performance, a model for the energy consumption is proposed. It has been proven that for an efficient SBS/RS design, both throughput performance and energy consumption aspect should be considered simultaneously.

It is believed that environment aspect will indubitably bring changes into planning of warehouses and will mean great challenge for those who are engaged in the planning process.

7. REFERENCES


APPRAOCH TO DETECTING PROMISING AREAS FOR IMPROVEMENT IN PRODUCTION PROCESSES

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Abstract

In production companies times and types of necessary logistics activities are often not recorded in the database of business information systems. In the technological procedures are generally recorded only preparatory closing times and piece times. This situation is problematic in cases when areas with potential for improvement in terms of time savings are looked for.

This paper offer a methodology for a systematic approach to seeking time reserves in production processes organised on functional or process layout. We are aware that it is not enough to show only on certain activities in process within which a lot of time without any added value for the customer is consumed but it is also important to show the type of causal area from which certain delay originate, for example technology, work organization, IT support, administration, staff, means of transport, etc... In this way, basis for fast search of solutions are prepared.

Methodology is used and upgraded in the process of students’ transition from academic to practical environment, for the purpose of practical training.

Key words: intralogistics, methodology, process improvement, cell layout.

1. INTRODUCTION

This paper has, in the main, been motivated by current events in Slovenian wood processing and metal processing sectors, specifically in small and medium-sized enterprises with production processes organised on functional/process layout. The utilisation of installed capacity is in those sectors rather low. During the observation of current situation and search for opportunities for improvement in more than dozen companies in Slovenia, we were very scant served with the information we needed to determine the rationality of potential improvements in area of logistics. Initially we started the research because we agree with Christopher [1] who wrote that “the cost of satisfying customer demand can be significant and yet, surprisingly, they are not always fully understood by organizations”. Whilst logistics costs will vary by company and by industry, across the economy as a whole that total cost of logistics as a percentage of gross domestics product is estimated to be close to 13 percent in the Europe [2].

Companies could increase the level of overall utilisation by various approaches, for example by implementation of Total Productive Maintenance (TPM). Its implementation has shown considerable results in Japanese enterprises. It has not been unusual to increase the level of overall utilisation from 60 to 90 percent according to Nakajima [3] which indicates a major increase of production. But the implementation of TPM is a difficult process of corporate change as reported Ljungberg [4]. Shaffer and Thomson [5] have also observed that most companies implementing “total quality” or “continuous improvement” fail to achieve results. Their mission is to focus on results rather than on activities. Ljungberg [4] further notes that if the magnitude and reasons for losses are not known, the activities will not be allocated towards solving the major losses in an optimal way. If measurable results are not provided within a rather short period, the management and operators can loose reliance in any introduced concept. A tool for measuring and evaluating the effectiveness of TPM can be found in “Overall Equipment Effectiveness” (OEE).

Production companies are mostly focused on productivity, which is most frequently showed with indicators. Those indicators are aforementioned OEE, Single Resource Productivity (SRP) in Total Resource Productivity (TRP). They have one thing in common and that is to evaluate how effectively a manufacturing operation is utilized. In case that they show the kind of significant inefficiency, the question arises about the reasons for situation. Furthermore, it is impossible to show how much inefficiency is on the side of the technological process, and how much of it is on the side of the logistics. Investments and reorganizations in logistics, in the aforementioned segment of companies, are extremely restrained, although logistics experts recommend upgrading. Our ultimate goal in the future will definitely be to show properly structured analytic of calculated productivity indicator in a way that will be ready for putting immediate proposals therapy for the production system. But we also noted that before mentioned companies mostly do
not use OEE, SRP or TRP. Established measurements are used more for a comparison between time periods than for a
discussion on the causes or as a basis for continuous improvement.

We developed a kind of process analysis for a systematic approach to seeking time reserves in production processes
organised on cell layout in small and medium-sized enterprises without established measurement system for continuous
improvement. We are aware that it is not enough to show only on certain activities in process within which a lot of time
without any added value for the customer is consumed but it is also important to show the type of causal area from
which certain delay originate, for example technology, work organization, IT support, administration, staff, means of
transport, etc... In this way, basis for fast search of solutions are prepared.

Methodology is used and upgraded in the process of students´ transition from academic to practical environment, for the
purpose of practical training.

Firstly, we introduce the idea of manufacturing performance measurement system and basic approach to process
analysis. We continue with presentation of our improved methodology in accordance with the literature review and with
regard to the needs of specific group of companies, small and medium-sized enterprises with production processes
organised on cell layout without established measurement system for continuous improvement. We conclude the
contribution with the presentation of selected results and directions for future research work.

2. MANUFACTURING PERFORMANCE MEASUREMENT SYSTEM

Ljungberg [4] noted that “the notion of throughput is considered by the operations management literature as a part of
performance measurement”. The throughput can be quantified as output/machine hour or capacity utilised.
Alternatively, focus can be put on reducing idle time and downtime according to Wild [6]. In any case, measures should
be taken also to shorten other kinds of activities in the process, if it is possible.

According to Nakajima [3], TPM, a concept for corporate change, includes a way of defining overall equipment
effectiveness (OEE). The definition of OEE includes downtime and other production losses which reduces throughput.
Three dimensions of effectiveness are availability, performance rate and quality rate. The definition of OEE does not
take into account all factors that reduce the capacity utilisation, e.g. planned downtime, lack of material input, lack of
labour etc. OEE is just a useful part of a complete overall manufacturing performance measurement system.

Researchers have measured downtime and classified the downtime in different ways. Bennett and Jenney [7] have
divided failures into types i.e. hydraulic, mechanical, electrical and electronic. Wiendahl and Winkelhake [8] divided
causes for analysed automated assembly plants and focused on “standstills” and divided those into technical and
organisational causes. Ericsson and Dahlén [9] divided the downtime in planned stop and unplanned stop. Further, the
downtime was divided into labour, maintenance, set-up and other. Also the rejects were measured. Ljungberg [4]
summarises: “Many enterprises do measure downtime in one way or another. In most cases, downtime is measured in
an ad hoc manner. The downtime is often recorded as repair-time. Minor stoppages are, in many cases, not considered.
Neither are speed losses.”

Ljungberg [4] also noted that “The data collection problem is not sufficiently treated in the TPM literature”. Concepts
and models are widely understood and validated but collection of trusted data is something left to the inventiveness.
Usually several complementary systems are used: systems for collecting data on machinery disturbance, administrative
maintenance systems for collecting data on the repair time (not equal as stoppage time), log books for collecting data on
major stoppages. Ljungberg [4] concluded that neither of those data collection systems gives an appropriate and
comprehensive picture of the losses and their reasons. The objective for future research of data collection should be
finding a method that is not time-consuming and is at the same time precise. It is necessary to convince operators and
foremen that data collection is necessary. Manual data collection systems are, in comparison with automatic data
collection systems, cheaper, less complex, more detailed and failures can be carefully examined. We consider
proceeding from Ljungberg [4] that because there is no unified picture about losses and their reasons there is also no
general agreement on the magnitude of different types of losses, nor on the reasons for losses.

Schmenner and Vollmann [10] showed in an empirical study that most studied companies needed seriously to consider
changing their performance measurements. They argued that most firms were both using wrong measures and failing to
use the right measures in correct ways. Jonsson and Lesshammar [14] assessed this as serious and it therefore seems
important to identify the critical dimensions in a performance measurement system (what to measure) and the optimum
characteristics of the measures (how to measure).

Ghalayini and Noble [11] proposed that new performance measurement systems should be dynamic and stress the
importance of time as a strategic performance measure.

Jonsson and Lesshammar [14] propose: “When designing performance measurement systems it is necessary to decide
first, what to measure, and second, how to measure. The dimensions “strategy”, “flow orientation”, “internal efficiency”
and “external effectiveness” of the present framework mostly describe the “what to” question. It is not enough to
identify what dimensions to measure; the measures also need to be designed so that the performance information can be successfully used. The way may differ between systems with different objectives. However, the characteristics “improvement drivers” and “simple and dynamic” describe the “how to” question. “

Efficient flow of materials and short throughput times depend on effective manufacturing. As suggested Jonsson and Lesshammar [14] we should therefore measure horizontal business processes instead of functional processes. This leads to flow-oriented measures. One way of switching to flow orientation is to measure times and throughput volume (e.g. [12]).

According to Ishikawa [13], the reason for collecting data should not be to present neat figures, but to create a base for action and development of processes. The set of measures should cover those aspects that indicate potential future improvements and the measure should in itself identify and generate continuous improvements, instead of working as passive control. [14]

In this article we try to find established measurements that show the causes of inefficiency arising from logistics. Lack of material as a cause for low OEE can be considered to be an internal logistics problem. We note that metrics are result of each business strategy separately. For example if logistics is identified as one of several manufacturing performance capabilities, service level and lead time are the tasks that should be performed by manufacturing. Even today we can agree with the findings of Jonsson and Lesshammar [14] that a common weakness of most measurement systems is that they do not measure flow orientation or external effectiveness to any great extent. They focused on functional measures and failed to integrate processes along the supply chain in the measurement system. Most of them use quite passive measures for controlling the external effectiveness and customer satisfaction, but most have several, more or less relevant, measures for internal efficiency.

3. PROCESS ANALYSIS BASED ON ASME STANDARD

Operation and Flow process charts as techniques of motion and process analysis were originally developed by Frank and Lillian Gilbreth. They defined process charts as “a device for visualizing a process as a means of improving it. Every detail of a process is more or less affected by every other detail; therefore the entire process must be presented in such form that it can be visualized at once before any changes are made in any of its subdivisions. In any subdivision of the process under examination, any changes made without due consideration of all the decisions and all the motions that precede and follow that subdivision will often be found unsuited to the ultimate plan of operation” [16].

ASME standard was approved on May 21, 1947. It defines a flow process chart as a graphic representation of the sequence of all operations, transportations, inspections, delays, and storages occurring during a process or procedure, and includes information considered desirable for analysis such as time required and distance moved. That is only one of many techniques that identify the different types of activity that take place during the process and show the flow of materials or people or information through the process.

According to ASME standard, for analytical purposes and to aid in detecting and eliminating inefficiencies, it is convenient to classify the actions which occur during a given process into five classifications. These are known as operations (produces and accomplishes), transportation (moves), inspection (verifies), delays (interfere), and storages (keeps). In case of unusual situations outside the range of the definitions for classifications are encountered, standard proposes the intent of the definitions to enable the analyst to make the proper classification.

In the early 70s, Graham introduced two variations of the operation symbol that were incorporated into a revised ASME Standard [15]. They are used to show "value-added" steps in information processing. Those are origination and Add/Alter. An origination represents the creation of a record or a set of papers. The “add/alter” represents an addition or change of information on an existing record or set of papers.

The aim of the process chat has remained the same as that from 1927: “to present information regarding existing and proposed process in such simple form that such information can become available to and usable by the greatest possible number of people in an organization before any changes whatever are actually made, so that special knowledge and suggestions of those in positions of minor importance can be fully utilized” [16].

4. STARTING POINTS FOR RE-USE OF ESTABLISHED POSITIONS TAILORED TO THE CURRENT BUSINESS ENVIRONMENT

Today, two of the mega trends in business environment are certainly globalization and customer orientation. Globalization has become another word for world commerce, which often has negative connotations. But globalization has had also a positive impact on the world economy in terms of increased competition and more efficient markets. All kind of companies have had to adapt to this with enhanced flexibility and lower operating costs. If companies had not yet developed a system of continuous improvement, is now that relentlessly required of them by developments in
environment. The Heskett’s\(^1\) statement is more and more true: “A refrigerator is not a refrigerator, if it is located in Detroit, and is required to Houston”. Companies are aware of the importance of logistics which gives the value to the products.

Logistics plays a vital role in economic systems and in everyday life. Given the significant cut back in manufacturing and work force costs, reducing logistics costs has become an increasingly important task for managers. On account of the complex supply chains and globalization, the cost of logistics operations could comprise as much as half the value of general commodities. [18]

The level of logistics costs is heavily dependent on the industry, but in general tends to be high in logistics - intensive operations such as food, metal, chemical and paper manufacturing [19, 20].

The literature suggests several levels on which the components of logistics costs can be broken down, ranging from three broad levels to very narrow component ranges. Sople, for example, identified three levels: transportation, storage and inventories [21], whereas Rushton, Croucher and Baker [22] include four cost components: transportation, inventory - carrying, storage/warehousing and administration costs. Ayers [23] ended up with five components: purchased materials and the associated labour, transportation, warehousing, inventories, and packaging [23]. Examples of more detailed cost breakdowns include Bidgoli’s seven components and Kivinen and Lukka’s 12 [24].

Figure 1 shows levels of logistics costs in statistics-based studies as a percentage of GDP (*% of sales). The geographical coverage of the study in question, as well as the year to which the data applies is indicated in each case. The level of logistics costs varies rather widely among the studies conducted in different geographical areas [17]. Companies certainly should aim to reduce logistics costs in order to increase the competitiveness.

There is increasing pressure to produce and distribute faster and cheaper. Time management is extremely important also on production sites where we do not have the feeling that logistics plays an important contribution to efficiency and effectiveness. Trendy application of lean thinking to production requires that all type of unnecessary productivity losses be eliminated or reduced. A large part of losses can be accounted on logistic activities. In order to improve lead time it is certainly important to find the way to show on certain activities in production process within which a lot of time without any added value for the customer is consumed.

We focused on Slovenian wood processing and metal processing sectors, specifically in small and medium-sized enterprises with production processes organised on functional/process layout. This choice determines some common characteristics of the selected enterprises. Mostly they:

- dispose with limited resources to invest in any kind of development;
- have lack of employees who are trained and free to deploy any kind of manufacturing performance measurement system;
- have limited financial resources to invest in the development and implementation of new technologies;
- are not aware of the existence of reserves on side of logistics;
- have limited options for automation;
- have not install the mechanism of continuous improvement yet;
- are familiar with the principles of lean production, but practical implementation is weak.

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\(^1\) James L. Heskett is Baker Foundation Professor, Emeritus at the Graduate School of Business Administration, Harvard University.
For process layouts, the relative arrangement of departments and machines is the critical factor because of the large amount of transportation and handling involved. Process layout design determines the best relative locations of functional work centres. Work centres that interact frequently, with movement of material or people, are located close together, whereas those that have little interaction are spatially separated. The production is organized as batch. All machines performing similar type of operations are grouped at one location in the process layout, e.g. all saws, polishing machines, etc. This kind of layout is normally used when the production volume is not sufficient to justify a production line. Work centres that interact frequently, with movement of material or people, are located close together, whereas those that have little interaction are spatially separated. The production is organized as batch. All machines performing similar type of operations are grouped at one location in the process layout, e.g. all saws, polishing machines, etc. This kind of layout is normally used when the production volume is not sufficient to justify a product layout. According to Kumar and Suresh [25] limitations of process layouts are:

- Backtracking and long movements may occur in the handling of materials thus, reducing material handling efficiency.
- Material handling can not be mechanised which adds to cost.
- Process time is prolonged which reduce the inventory turnover and increases the in process inventory.
- Lowered productivity can be observed due to a number of set-ups.
- Throughput (time gap between in and out in the process) time is longer.
- Space and capital are tied up by work-in-process.

From the list of limitations we can quickly realize that most of limitations are related to logistics. In such production facilities, in addition to machines, there are still many chaotically distributed transport logistics units with material, semi-products, products, and means of transport (Figure 2).

**Figure 1** - Levels of logistics costs in statistics-based studies as a percentage of GDP (* % of sales)

**Source:** Rantasila & Ojala [17]

![Figure 1](image1.png)

![Figure 2](image2.png)

**Figure 2** - Example of chaotically distributed transport logistics units in production plant
5S method is usually completely unknown between focused companies because companies from the automotive branch were excluded from research.

We can conclude this chapter with following conclusion. Today companies can implement value stream mapping, Kaisan, OEE, SRP, TRP or a complete overall manufacturing performance measurement system. They can also document their processes for audit or certification. But specific group of companies that we selected for our study just can not afford all this. Those systems involve a lot of administration, time and money. This specific group of companies is open to a lot more simple solution that would help them to improve themselves faster, cheaper and better.

5. THE METHODOLOGY DEVELOPMENT

We were spontaneously developing methodology for process analysis at the Faculty of Logistics, University of Maribor, through the last six years. At the beginning we started with pure usage of ASME standard for flow process chart. We needed flow process chart to present information regarding existing and proposed processes in a simple form that such information can become immediately applicable by our students and employees in observed company before any changes whatever are actually made, so that the special knowledge and suggestions of those in positions of minor importance, skills and knowledge can be fully utilized.

Process flow charts were produced by groups of students who have followed the flow of material through the manufacturing plant and recorded the sequence of actions, determined the type of each activity, measured the duration of each activity, measured travelled distance and filled the data into the pre-prepared table (Figure 3).

<table>
<thead>
<tr>
<th>Quantity/unit charted</th>
<th>Symbols</th>
<th>Description of event</th>
<th>Distance moved [m]</th>
<th>Unit oper time</th>
<th>Unit mpi time</th>
<th>Unit inspect time</th>
<th>Delay time</th>
<th>Storage time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 palette</td>
<td>□□□□□□□□□</td>
<td>Moved to delivery point</td>
<td>105</td>
<td>120 s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 box</td>
<td>□□□□□□□□□</td>
<td>Moved to machine</td>
<td>1</td>
<td>20 s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>□□□□□□□□□</td>
<td>Box waste for operator</td>
<td></td>
<td></td>
<td>2 min</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3** - Example of flow process chart fragment for existing process

We noticed that production process flow charts have several advantages when used to search for improvements opportunities by inexperienced people who do not know the methodology and the details about investigated process. Preparation for the observation is very fast because it is a method that can be learned by persons who have no previous experiences. Using cameras can be a good solution to bridge possible uncertainty concerning the classification of certain activities.

After several uses (more than 20 manufacturing companies) we gathered some weaknesses of the basic procedure:
- From the process flow chart we could not directly read the ratio between the value adding time and process time.
- Logistics activities could not be easily separated from production ones, excluding transportation and storage. It is important to point on all logistics and transportation activities because management staff in production companies do not easily believe that reserves lie in logistics and specifically they have problems with estimating the proportion of logistics and transport costs in the total cost of operations.
- As delay can be characterized two types of activities. The first type of activities comprise those that are necessary to complete the process and the second type of activities comprise those that are not associated with the process at all – process will continue even if this step is completely eliminated.
- We noticed that logistics activities in production environments (intralogistics) do not add value for the customer who orders products. But they are definitely needed for process completion. The situation is completely different in a case of a transport company which sells transportation services. In production companies, internal transport does not add value to products, but in case of transport companies it does.
- It is difficult to understand the practical value of technological and administrative activities equation under “operations” as proposes ASME standard. According to ASME “an Operation occurs when an object is intentionally changed in any of its physical or chemical characteristics, is assembled or disassembled from another object, or is arranged or is arranged or prepared for another operation, transportation, inspection, or storage. An operation also occurred when information is given or received or when planning or calculating takes place.

We introduced four types of activities rather than just value-added and non value-added activities/times. Those are:
- beneficial – activities/time that are directly related to a product/service that is the subject of the contract. In the case of ordering wooden tables those are sawing, polishing, painting, coating, screwing, and so on;
• non-beneficial – activities/time that not directly related to a product/service that is the subject of the contract. In the case of ordering wooden tables those are moving materials and semi-finished between jobs, working with documents, taking material from pallets, machines settings, and so on;
• necessary – activities/times that are strictly necessary for realization of client orders. In the case of ordering wooden tables those are all of the above;
• unnecessary – activities/times which are not in any way related to the customer order and are fully redundant. In the case of ordering wooden tables those are coffee, private conversation with a colleague, checking missed calls, browsing the Internet.

From proposed we can form 3 meaningful pairs:
• beneficial – necessary (add value);
• non-beneficial – necessary (do not add value);
• non-beneficial – unnecessary (fully redundant).

Pair “beneficial – unnecessary” is in practice non-existent combination.

We have also started to use the additional character for work with documents, namely "diamond". Today's level of technological development enables a completely paperless operation and tends to the “Internet of Things”, which described Bendavid, Wamba and Barjis [26]. Organization of work with documents is a great challenge today and the work can be organized in a number of alternatives. Many companies are not able to assess what portion of process at all occupies the work with documents.

In the original table in Figure 3, we replaced initial types of time with proposed and added an additional symbol for work with documents. Original types of time (unit operation time, unit transportation time, unit inspection time, delay time storage time) did not enough encourage the search for causes and solutions for improvement.

<table>
<thead>
<tr>
<th>Quantity unit charted</th>
<th>Symbols</th>
<th>Description of event</th>
<th>Distance moved [m]</th>
<th>beneficial – necessary time</th>
<th>non-beneficial – necessary time</th>
<th>non-beneficial – unnecessary time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 palette</td>
<td>● ▼ □</td>
<td>Moved to delivery point</td>
<td>105</td>
<td>120 ¤</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 pallet</td>
<td>● ▼ □</td>
<td>Confirmation of the movement from the warehouse</td>
<td>10</td>
<td></td>
<td>10 ¤</td>
<td></td>
</tr>
<tr>
<td>1 box</td>
<td>● ▼ □</td>
<td>Moved to machine</td>
<td>1</td>
<td>20 ¤</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>● ▼ □</td>
<td>Operator checks missed calls</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4** - Structurally improved flow process chart fragment for existing process

In such a manner, we successfully separated pure technological activities from other. In production companies, times and types of necessary logistics activities are often not recorded in the database of business information systems. Also, in the technological procedures are generally recorded only preparatory closing times and piece times. Companies do not have any sense of how much time they spend for logistics and transport activities, downtimes or even for with the process entirely unrelated activities. As mentioned earlier, deploying proven methods is often too complex and expensive. Development of own methodology requires knowledge, time and engages operators and the superiors in terms of making notes and records keeping. But notes are not entirely trustworthy, because operators want something deliberately conceal, hide, often forget to record, and the like. It is even questionable if it is necessary to constantly monitor the situation. We believe that it is advisable to monitor occasionally those processes that bring the majority of revenues and that this is done fully automated or by an independent person who is not engaged in the implementation of process activities.

The observations were always performed several times through different shifts (night, morning), at rush hours and non-rush hours. Flow process chart was made each time. Normally, we performed five repetitions, preferably using the camera, without prior notice.

To be able to combine longer times with the causes for them, we first listed all the resources that are necessary for the each cycle of the observed process and second we distributed them in large groups. Our groups were: Material; Technology; Documentation; Employees; Organization of work; Environment; Information and communication support. Each of them can be a potential cause of inefficiency. We noticed that our groups of resources were much the same as categorized causes in the Ishikawa diagram, known as 6M’s: Machine (technology); Method (process); Material (includes raw material, Consumables and Information); Man Power (physical work)/Mind Power (brain work); Measurement (Inspection); Milieu/Mother Nature (Environment). These groups can after words label categories of the...
fishbone, which was in practice very often used, but always supplemented by data on the frequency of repetition of individual causes and the total time spent in the observation period. Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behaviour. We also encourage the use of 5 Whys technique to trace causes back to root causes.

6. THE RESULTS FROM IMPLEMENTATION FAZE

In this report we included results of work in the twenty-eight companies from wood processing and metal processing sectors, precisely small and medium-sized enterprises with production processes organised on functional/process layout. Those companies do not have established mechanism for continuous improvements and are not even interested in launching any of the established concepts. But they want to improve their processes and do not know where or how to start. They will be motivated only by concrete results in a short time without much engagement of their own work force. They look for the professionals who would later also be hired to design a tailored system for processes improvement. It could be said that the proposed methodology can be adapted for establishment of contact between faculty and businesses, but we think it is useful more broadly, for consulting firms and for manufacturing companies of mentioned type.

All companies have confirmed the results and find them as a good starting point for the preparation of development projects. The thirds of the companies subsequently recruited students of our faculty.

Average cycle time in observed processes lasted 29 hours, of which we observed in average:

- 53 percent of beneficial and necessary time (preparatory closing times and piece times);
- 36 percent of non-beneficial but necessary time (all logistics and transportation, administration work, inspection, necessary delays);
- 10 percent of non-beneficial and also unnecessary time (activities which are not in any way related to the customer order and are fully redundant).

In the observed companies, it was possible to shorten production lead time on average by 10 percent without any investment, usually with only minor organizational changes. 36 percent of time on average was spent on logistics and transportation (22 %), administration work (8 %), inspection (4 %) and necessary delays (2 %). By investing in logistics and transportation it would be possible to reduce the lead time on average by maximum of 22 %. Long lead times were in average mostly the result of a long search times (logistic units), indeterminate organisation of work, duplications of tasks, absence of detailed scheduling, lower and basic IT support, lack of prevention in the field of quality assurance, not optimal layout, disadvantageous features of workshop.

7. CONCLUSIONS

Companies could increase the level of overall utilisation by various approaches, for example by implementation of total productive maintenance (TPM) up to 90 percent. The implementation of “total quality” or “continuous improvement” is not a guarantee to achieve results. Additionally, if measurable results are not provided within a rather short period, the company staff can lose reliance in any introduced concept. In a case of companies from wood processing and metal processing sectors, precisely small and medium-sized enterprises with production processes organised on functional/process layout, they are not interested in launching any of the established concepts. This is because they associate the induction process with high costs and the vagueness effects. But they although want to improve their processes and do not know where or how to start. We noticed that they can be motivated only by cheap approach, concrete results in a short time without much engagement of their own work force. Those companies do not have established mechanism for continuous improvements.

It is not enough to show the kind of significant inefficiency, the question arises about the reasons for situation. Without known reasons the improvement is practically impossible and investments and reorganizations in logistics, in the aforementioned segment of companies, are extremely restrained.

We developed a kind of process analysis for a systematic approach to seeking time reserves in production processes organised on cell layout in small and medium-sized enterprises without established measurement system for continuous improvement. Methodology is used and constantly upgraded in the process of students’ transition from academic to practical environment, for the purpose of practical training.

Focus is put on reducing cycle and not only idle time and downtime. To do so data collection is required and that is not sufficiently treated in the TPM literature. Concepts and models are widely understood and validated but collection of trusted data is something left to the inventiveness. We propose manual collection of data by third parties. Manual data collection systems are, in comparison with automatic data collection systems, cheaper, less complex, more detailed and failures can be carefully examined.
Proposed methodology is dynamic and stresses the importance of time as a strategic performance measure. We measure horizontal business processes instead of functional processes. The set of measures cover those aspects that indicate potential future improvements and the measure in itself identify and generate continuous improvements.

We have improved Flow process chart as technique of motion and process analysis, originally developed by Frank and Lillian Gilbreth. That is only one of many techniques that identify the different types of activity that take place during the process and show the flow of materials or people or information through the process. We added additional the sixth classifications (diamond) for work with documents and therefore improve analytical value. We introduced four types of activities rather than just value-added and non value-added activities-times. Those are: beneficial activities/time; non-beneficial activities/time; necessary activities/times; unnecessary activities/times. From proposed we formed 3 meaningful pairs: beneficial – necessary (add value); non-beneficial – necessary (do not add value); non-beneficial – unnecessary (fully redundant).

To be able to combine longer times with the causes for them, we first listed all the resources that are necessary for the each cycle of the observed process and second we distributed them in large groups. Our groups were: Material; Technology; Documentation; Employees; Organization of work; Environment; Information and communication support. Each of them can be a potential cause of inefficiency. These groups can after words label categories of the fishbone, which was in practice very often used, but always supplemented by data on the frequency of repetition of individual causes and the total time spent in the observation period. Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behaviour. We also encourage the use of 5 Whys technique to trace causes back to root causes.

In the observed companies, it was possible to shorten production lead time on average by 10 percent without any investment, usually with only minor organizational changes. 36 percent of time on average was spent on logistics and transportation (22 %), administration work (8 %), inspection (4 %) and necessary delays (2 %). By investing in logistics and transportation it would be possible to reduce the lead time theoretically on average by maximum of 22 %. Long lead times were in average mostly the result of a long search times (logistic units), indeterminate organisation of work, duplications of tasks, absence of detailed scheduling, lower and basic IT support, lack of prevention in the field of quality assurance, not optimal layout, disadvantageous features of workshop.

We proposed a simple solution that could help specific companies to improve themselves faster, cheaper and better. They can also recognize potential employees that have talent and knowledge for designing the tailored system for constant improvements.

8. REFERENCES

individual causes and the total time spent in the observation period. Cause-and-effect diagrams can reveal key support. Each of them can be a potential cause of inefficiency. These groups can after words label categories of the Technology; Documentation; Employees; Organization of work; Environment; Information and communication each cycle of the observed process and second we distributed them in large groups. Our groups were: Material; To be able to combine longer times with the causes for them, we first listed all the resources that are necessary for the unnecessary (fully redundant).

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They can also recognize potential employees that have talent and knowledge for designing the tailored system for quality assurance, not optimal layout, disadvantageous features of workshop.

Proposed methodology is dynamic and stresses the importance of time as a strategic performance measure. We measure necessary (add value); non-beneficial (necessary (do not add value); non-beneficial
GREENING TRANSPORT ACTIVITIES IN THE FOOD RETAIL SUPPLY CHAIN

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Abstract
Over a decade there has been a growing pressure on retail companies to transform their operations to become more effective from a green perspective. Improved customer relationships, improved brand image, increased efficiency and improved customer services are significantly stronger drivers of such green initiatives. Literature differs concerning the scope and number of retail operations and activities, but it agrees that transport and logistics activities have caused the highest costs and have been insufficiently investigated as well. This paper explains whether improvements in transport and logistics services at the same time could result in costs reductions and improvements in the ecological performances of food retail companies. In other words, the paper is investigating the impact of food retailers’ green initiatives on the way they manage their transport and logistics services. For the purpose of the paper, a quantitative study on the sample of 190 food retail companies operating on the Croatian market was conducted. The findings suggest an overall positive image towards green transport activities, however usage of green transport and logistics activities differ among observed food retailers.

Keywords: green transport, food retail, food supply chain management, Croatia

1. INTRODUCTION
In order to face today’s growing pressure of a changing retail environment and to obtain the competitive advantage on the market, retailers are forced to undertake some activities that go beyond profitability, focusing on goals such as ethical trading, responsibility to the community and society, environmentally sound management practices, measures for greening their supply chain, etc. Issues like environmentally friendly consumption, health issues, ethical food, fair global trade, union and human rights, environment, and global warming will confront retailers with "right" – or – "wrong" types of decisions [1]. Studies in the USA and the UK indicate that consumers’ buying decision is influenced by the performance of retailers on environmental issues [2]. As the population as well and their consumption continues to increase rise, increasing stress has been made on resources and environmental systems such as water, land and air [3]. Retail companies have realized the importance of the environment, as increasingly reflected in their strategies and daily business operations. In order to effectively deliver the environmental sustainability goals, they have already initiated many actions in their supply chains, shops, communication and in the products supplied to their customers, driving environmental sustainability not only in Europe but also on a global scale. Furthermore, retailers also cooperate with their suppliers and customers, as well with other stakeholders such as their employers, governments or NGOs, in order to promote environmental sustainability among a wide audience [4]. The concept of green has become a familiar key phrase in recent years as more and more companies have targeted the environmentally conscious consumers and have begun to respond to the stricter environmental regulations [5].
Trying to illustrate retailers’ environmentally conscious behaviour, it is worth mentioning the example of the retail giant Wal-Mart which has made an effort to reduce consumption of natural resources by pressuring its suppliers to become green-oriented [6]. Moreover, there are H&M stores which promote their clothes using the label 'Organic Cotton' accompanied by the following claim: 'organic cotton means environmentally friendly cotton that has been grown without the use of pesticides or synthetic fertilisers; it is healthier for cotton farm workers, better for nature and wonderfully soft and natural for you to wear' [5]. Both IKEA and Home Depot developed environmentally friendly product lines to appeal to a certain customer segment. Moreover, it is worth emphasizing that the green orientation of enterprises contains a whole range of values.

This paper begins with the theoretical framework for studying retailers’ green supply chain initiatives. The review of the available literature shows the scope and number of retail operations and activities where environmentally sound management practices are implemented. Moreover, it concludes that among them transport and logistics activities have caused the highest costs and have been insufficiently researched as well. For the purpose of getting better insight into the subject of the paper, green initiatives in transport and logistics taken by retailers were explored by conducting a quantitative study on the sample of 190 food retailers operating on the Croatian market. Thus, in the chapter that follows the literature review, a discussion on research methodology and results of the study is given. Finally, concluding remarks are given.

2. THEORETICAL FRAMEWORK ON THE RETAIL GREEN LOGISTICS ACTIVITIES

According to [7], traditionally retailing has not been considered an environmentally important industry. Furthermore, [8] support his statement and point out that scientific community is completely neglecting the environmental impact of retailing. It is interesting that in the period from 1972 to 1999 there was only one scientific work dealing with the environmental aspects of retailing. However, along with the growth of global economy, the range of retailers’ business activities has been spread, and retailers (particularly grocery retailers) have started with the implementation of environmentally responsible behaviour. According to [5], when discussions of environmental responsibility and green consciousness are raised, the focus is usually on manufacturers. Together with a social responsibility, environmental responsibility has been very often incorporated in the sustainability reports of retailers [9]. Literature suggests [10] that there is a wide array of green initiatives of retailers, both within the store and the supply chain. The fact is that almost 80% of environmental impact of products sold by the retailers usually occurs beyond the shop floor while only 20% can be attributed to the in-shop activities [11].

In this chapter, the most often considered environmentally responsible activities of retailers (such as green procurement, green supply chain, green storage, green transportation, reverse logistics) are briefly explained [12, 13]:

a) **Green procurement** – explains that in the process of products procurement retailers should consider the green degree including the product itself and product packaging by giving more concessions to the higher green degree of brand to urge the manufacturer toward green direction. However, the balance between the theory and the implementation of green procurement due to the slow process of the implementation is doubted [14];

b) **Green supply chain** – suggests that the supply chain structure and vehicle utilization strongly influence the environmental performance of the road freight transport sector. According to [13], the supply chain structure is determined by the number of links and their average length. The study of [15] confirmed that the co-operation with the suppliers improved ecological performances of the company as a whole. Additionally, suppliers’ ecological responsibility is one of the most important criterions for choosing suppliers [16];

c) **Green storage** – There are several requirements of green storage management such as creating secure storage environment, building rational distribution warehouse, developing an electronic inventory system, arranging reasonable inventory quantity and keeping safety of goods in the process of warehouse operations. It is estimated that warehousing accounts for 2-3% of total CO2 emissions [17];

d) **Green transport** – In order to implement green logistics, retailers should follow measures, such as establishing an electronic information system necessary to jointly coordinate logistics activities, using green vehicles which are more expensive than ordinary freight cars but provide the control of the pollution, choosing a reasonable delivery mode in order to increase the use of intensive resources and reduce duplication of vehicle transportation and emissions;
e) **Reverse logistics** – includes all activities associated with a product/service after point of sale, the ultimate goal to optimize or make more efficient aftermarket activity, thus saving money and environmental resources. The issue of ‘greening’ added an additional dimension to the reverse logistics because manufacturers and retailers in certain markets are obliged by law to take back their products at the ‘end of life’ and recycle them [18].

In such a way, a comprehensive framework necessary for understanding the concept of retailers’ green initiatives is provided. All the above mentioned activities are involved in the system architecture of the green logistics whose purpose is to reduce costs, improve efficiency, develop sustainability of the company, etc. The concept emerged in the 1990s as the ‘former’ logistics organized with the purification of the logistics environment and no damage to the environment.

According to [19] the retail sector can contribute to sustainable consumption and production activities in the following three main areas:

- **Cleaner production and environmental management systems** – The retail sector can first control and manage its own environmental and social impact through implementing environmental management systems for energy/water conservation, waste management, logistics, recycling programs, etc.

- **Supply chain management** – Retailers can co-operate with their suppliers and favour the development of products featuring enhanced environmental and/or social attributes. Efforts such as greening the supply chain and implementing green purchasing can encourage suppliers to develop eco-friendly products, and to provide information on the sustainability aspects of their products notably through eco-labels.

- **Education and information of customers** – Retailers can encourage consumers to purchase eco-friendly products as well as provide advice on the use and disposal of the products and offer facilities and services such as take-back systems for batteries, reusable bags, etc.

On the one hand, the retail sector can influence suppliers to produce in a more sustainable manner (for example, by raising questions of resource and energy use) and, on the other hand, the retail sector is in a unique position to help the public to adopt more environmentally friendly lifestyles and purchasing habits by providing customers with an appropriate choice [20].

3. **ENVIRONMENTAL CHALLENGES FOR THE RETAIL TRANSPORT**

The continued upward trend in global sourcing has inevitably led to products travelling greater distances. Both the increase in food trade as well as the current organization of food chains has forced processors and manufacturers to start thinking of ‘food miles’ adding the distance ingredients travel to the growing list of environmental concerns they must take into consideration [21]. Moreover, the distribution of fast moving consumer goods takes place through supermarket regional distribution centers using larger heavy goods vehicles, which has an impact in the areas of road congestion, damage to infrastructure and road accidents. The final result is an increase in what might be termed as the transport-intensity of the supply chain [22]. By improving the transport intensity supply chain members could gain not only economic benefit, but also could have a potential positive environmental impact.

[23] and [24] are discussing logistics efficiencies obtained through centralized deliveries rather than direct to store deliveries. The links between transport and environmental considerations are not necessarily related to the kilometers of goods travelling, yet they are complex and involve a number of trade-offs [25]. Responding to the challenges they are facing, both in terms of environmental and economic aspects, retailers are engaging in a number of solutions such as intermodal transport [26].

In order to improve the transport-intensity of the supply chains, companies can [22]:

1. **Review product design and bill of materials**

   Product design can impact transport-intensity through the physical characteristics of the product, its density, the choice of materials (including packaging materials), the ease of recycling, reuse and end-of-life disposal.

2. **Review sourcing strategy**

   Many sourcing decisions have led to a migration to low-cost country locations. This often has led to products being moved greater distances. Global sourcing decisions will increasingly need to factor the carbon footprint to the total cost of ownership.
3. **Review transport options**

Clearly different transport modes have different impacts on carbon and other emissions. The design of vehicles and vessels is also increasingly influenced by the need to improve fuel efficiency. There are also arguments for increasing the size of vehicle or the vessel to achieve lower transport intensity per unit.

4. **Improve transport utilisation**

Research has highlighted that vehicle capacity is often poorly utilized. It is suggested that empty running because of the lack of return loads means that up to a third of the trucks on the roads of Europe are running empty. More use of shared distribution, better vehicle routing and scheduling, and better loading can also dramatically improve transport-intensity.

5. **Use postponement strategies**

If standard, generic products can be shipped in bulk from their point of origin and then assembled, customized or configured for local requirements nearer the point of use, there may be an opportunity to reduce overall transport-intensity.

As mentioned before, literature agrees about the contribution of retail transport and logistics activities to the company’s overall environmental responsibility. The EU 2009 Renewable Energy and Fuel Quality Directives set targets of a 10% share of renewable energy in the transport sector and a 6% greenhouse gases reduction for fuels used in the transport sector in 2020. Over the medium term, some improvements can be achieved through the use of hybrid and electric vehicles, while natural gas and biogas may be used in larger vehicles instead of diesel. In such a way, savings from 15-50% could be obtained [25].

4. **RESEARCH METHODOLOGY**

For the purpose of this paper, research study examining the perceptions of food retailers’ on the importance for implementing environmentally responsible activities in managing their transport and logistics services was conducted. The method used in this study was a survey questionnaire, which was constructed based on the summative content analysis and interviews with experts from practice who engage in everyday activities and are familiar with environmental initiatives in food retail supply chain management.

The research instrument was pretested on the sample of experts from food retail practice, such as supply chain managers, logistics directors, retail directors, retail store owners, which is usual research practice in conducting empirical research among businesses. The research was conducted from April to September, 2013. From the 210 research questionnaires collected during this time, 190 were completely correct and eligible for further analysis. As the research was conducted on the business market, the response rate is satisfactory, especially when taking into account that retailers are not keen to participate in the research, either because of lack of time or they do not want to share information regarding their business activities.

The questionnaire about food retail supply chain management consisted of the following major sections. In first part of the questionnaire the data about retailers were collected, in second part respondents were asked to assess the relationship of the business entity towards environment, while in the third part of the questionnaire, the respondents were asked to assess implementation of green activities in their supply chain. Respondent’s perception of the implementation of environmentally responsible activities in retail supply chains were measured using multiple-item 5-point Likert scales adapted from previous studies, with strongly disagree (1) and strongly agree (5) as the anchors. Environmentally responsible activities in food supply chain which respondents were assessing were: 1) *environmentally responsible procurement*, 2) *warehousing*, 3) *transport*, and 4) *reverse logistics*. In this paper focus is on green transport in food supply chain management. As the original items were in English, we asked two researches whose native language is English to check the translation validity. The instrument gathered data on the retailers’ environmental responsibility via items adapted from literature review.

5. **RESEARCH RESULTS**

5.1. **Description of the sample**

Food retailers that participated in the research (*Table 1.*) have operated in a variety of legal forms. The highest percentage of them were mainly private limited liability companies (65.3%), then tradesman/craftsman (26.3%), joint-stock companies (4.8%) and other organizational forms. According to
the form of ownership, almost the whole sample is of private ownership (96.3%), followed by cooperatives and mixed forms of ownership, each one with a share of 1.6% and one food retailer from the sample is in state ownership. Regarding the origin of capital, sample distribution is as follows: retailers dominate with domestic origin of capital (95.2%); 3.7% of respondents mentions foreign origin of capital and 1.1% of respondents mixed origin of capital.

The vast majority of food retailers are operating on the local market (84.7%). Some food retailers operate on the regional market (9.5%). On the national market there is a presence of 4.2% of food retailers, while 1.6% of food retailers mention that they operate on the international market. Considering the number of employees, more than half of the sample consists of retailers with up to 10 employees (57.4%), which can be characterized as small retailers. Then, in the sample we have represented retailers from 10 to 50 employees (20.0%), retailers with more than 250 employees (13.2%) and retailers from 50 to 250 employees (13.2%). A vast majority of retailers mention that the share of employees with higher education is less than 25% (89.5%), 10.0% of retailers mention a share from 25% to 50% of employees with a university degree. Only one retailer mentioned that a share of employees with higher education is between 50% and 75%, while there was no retailer in the category above 75% of employees with a university degree.

Table 1 – Sample characteristics related to food retailers ownership, size and market

<table>
<thead>
<tr>
<th>Legal form</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>joint-stock company</td>
<td>9</td>
<td>4.8</td>
</tr>
<tr>
<td>private limited liability</td>
<td>124</td>
<td>65.3</td>
</tr>
<tr>
<td>public company</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>tradesman/craftsman</td>
<td>50</td>
<td>26.3</td>
</tr>
<tr>
<td>other organizational forms</td>
<td>6</td>
<td>3.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Form of ownership</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>private</td>
<td>183</td>
<td>96.3</td>
</tr>
<tr>
<td>state</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>cooperative</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>mixed</td>
<td>3</td>
<td>1.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Market</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>161</td>
<td>84.7</td>
</tr>
<tr>
<td>regional</td>
<td>18</td>
<td>9.5</td>
</tr>
<tr>
<td>national</td>
<td>8</td>
<td>4.2</td>
</tr>
<tr>
<td>international</td>
<td>3</td>
<td>1.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of employees</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 10 employees</td>
<td>109</td>
<td>57.4</td>
</tr>
<tr>
<td>from 10 to 50 employees</td>
<td>38</td>
<td>20.0</td>
</tr>
<tr>
<td>from 50 to 250 employees</td>
<td>18</td>
<td>9.4</td>
</tr>
<tr>
<td>more than 250 employees</td>
<td>25</td>
<td>13.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Share of employees with higher education</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 25%</td>
<td>170</td>
<td>89.5</td>
</tr>
<tr>
<td>from 25% to 50%</td>
<td>19</td>
<td>10.0</td>
</tr>
<tr>
<td>from 50% to 75%</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>more than 75%</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

TOTAL 190 100.0

Table 2. shows operating indicators of food retailers. The largest number of retailers operates with up to 50 food suppliers (65.3%), followed by retailers who are doing business with from 50 to 100 food suppliers (15.8%), retailers who are doing business with more than 250 food suppliers (8.4%), retailers who are doing business with from 100 to 150 food suppliers (6.3%). The lowest percentage of investigated retailers operates with 150 to 200 food suppliers (3.2%) and 200 to 250 food suppliers (1.0%).
Regarding the retail form, retailers who participated in the study, mostly operate in convenience stores (81.1%), mini markets (38.9%), supermarkets (16.3%), hypermarkets (5.8%), discount stores (3.2%), specialized stores (10.0%), drugstores (2.1%), and 8.4% in other food retail formats, besides the mentioned ones.

### Table 2 – Operating indicators of food retailers

<table>
<thead>
<tr>
<th>Total revenue in 2012</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 1 million HRK*</td>
<td>39</td>
<td>20.6</td>
</tr>
<tr>
<td>from 1 to 50 million HRK</td>
<td>115</td>
<td>60.5</td>
</tr>
<tr>
<td>from 50 to 100 million HRK</td>
<td>7</td>
<td>3.7</td>
</tr>
<tr>
<td>from 100 to 500 million HRK</td>
<td>20</td>
<td>10.5</td>
</tr>
<tr>
<td>from 500 to 1 milliard HRK</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>more than 1 milliard HRK</td>
<td>7</td>
<td>3.7</td>
</tr>
<tr>
<td>I do not know</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of suppliers of food products</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 50 suppliers</td>
<td>124</td>
<td>65.3</td>
</tr>
<tr>
<td>from 50 to 100 suppliers</td>
<td>30</td>
<td>15.8</td>
</tr>
<tr>
<td>from 100 to 150 suppliers</td>
<td>12</td>
<td>6.3</td>
</tr>
<tr>
<td>from 150 to 200 suppliers</td>
<td>6</td>
<td>3.2</td>
</tr>
<tr>
<td>from 200 to 250 suppliers</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>more than 250 suppliers</td>
<td>16</td>
<td>8.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revenue from sales of food products in total revenue in 2012</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 25%</td>
<td>26</td>
<td>13.7</td>
</tr>
<tr>
<td>from 25% to 50%</td>
<td>33</td>
<td>17.4</td>
</tr>
<tr>
<td>from 50% to 75%</td>
<td>78</td>
<td>41.0</td>
</tr>
<tr>
<td>more than 75%</td>
<td>53</td>
<td>27.9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>190</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*HRK – currency of Croatia (kuna). 1 EUR ≈ 7.4 HRK

### 5.2 Greening transport in the food retail supply chain

**Greening transport in the food retail supply chain** was operationalized using statements referring to: optimizing transport routes while respecting the environment, modernizing the transport fleet in order to reduce unnecessary exhaust emissions, using alternative fuels, consolidating transport shipments, better transport utilization, using information and communication technologies to improve transport route planning, sharing transport resources with other companies and monitoring CO2 emissions.

**Table 3.** shows descriptive indicators of research findings, mean and standard deviation for variables related to the greening of transport in the food retail supply chain.

### Table 3 – Descriptive indicators for greening transport in the food retail supply chain

<table>
<thead>
<tr>
<th>Item</th>
<th>x</th>
<th>sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>taking into account better transport utilization</td>
<td>4.24</td>
<td>0.851</td>
</tr>
<tr>
<td>consolidating transport shipments</td>
<td>3.89</td>
<td>1.100</td>
</tr>
<tr>
<td>optimizing transport routes in order to protect the environment</td>
<td>3.61</td>
<td>1.167</td>
</tr>
<tr>
<td>modernizing transport fleet in order to reduce unnecessary exhaust emissions</td>
<td>3.09</td>
<td>1.169</td>
</tr>
<tr>
<td>using information and communication technologies to improve transport route planning</td>
<td>3.01</td>
<td>1.442</td>
</tr>
<tr>
<td>sharing transport resources with other companies</td>
<td>2.52</td>
<td>1.417</td>
</tr>
<tr>
<td>using alternative fuels, such as gas, advanced biofuels</td>
<td>2.05</td>
<td>1.163</td>
</tr>
<tr>
<td>monitoring CO2 emissions in transport</td>
<td>1.97</td>
<td>1.105</td>
</tr>
</tbody>
</table>

*note: x – mean, sd – standard deviation*
Most food retailers, as many as 61.6% optimize transport routes in order to respect the environment. To reduce unnecessary exhaust emissions, 38.9% of food retailers regularly modernize their transport fleet. The use of alternative fuels in transport activity on the Croatian market is still in its infancy. Namely, over 70.0% of food retailers state that they do not use alternative fuels.

A great proportion of research participants (74.2%) consolidate shipments. However, future research should verify if the background is connected with an economic aspect or it is purely environmental. A great proportion of examinees (88.4%) take into account transport utilization. The use of ICT in order to improve transport planning of routes states 42.1% of food retailers, which is logical due to the significant number of small retailers represented in the sample. Food retailers in Croatia unfortunately do not follow an international trend in sharing transport capacities; 55.8% of respondents state that they do not share transport with other transport companies and an even fewer number of retailers (10.0%) monitor CO2 emissions. Based on the low average values of descriptive indicators for greening transport in the food retail supply chain, it can be concluded that Croatian food retailers lag far behind international food retail practice. From Table 3, it can be concluded that food retailers state the highest level of agreement with the statement that refers to a better transport utilization (\( \bar{x} = 4.22, \ sd = 0.851 \)), while the lowest level of agreement of respondents is with the statement of monitoring CO2 emissions in transport (\( \bar{x} = 1.97, \ sd = 1.105 \)).

Afterwards, in order to perform a factor analysis, a Kaiser-Meyer-Olkin (KMO) measure of the adequacy of sampling and Bartlett's test of sphericity were conducted. Since the value of the KMO test is satisfactory (k = 0.776) and the Bartlett test showed statistically significant (\( X^2 = 460,094, \ p < 0.01 \)), the prerequisites for the factor analysis were satisfied. A principal component factor analysis of eight statements connected with greening transport in the food retail supply chain was conducted. A principal component factor analysis of eight statements connected with greening transport in the food supply chain gives a two factor structure, as can be seen in the factor matrix (Table 4).

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>monitoring CO2 emissions in transport</td>
<td>.847</td>
<td></td>
</tr>
<tr>
<td>using alternative fuels, such as gas, advanced biofuels</td>
<td>.779</td>
<td></td>
</tr>
<tr>
<td>using information and communication technologies to improve transport route planning</td>
<td>.687</td>
<td></td>
</tr>
<tr>
<td>sharing transport resources with other companies</td>
<td>.676</td>
<td></td>
</tr>
<tr>
<td>consolidating transport shipments</td>
<td>.843</td>
<td></td>
</tr>
<tr>
<td>taking into account better transport utilization</td>
<td>.843</td>
<td></td>
</tr>
<tr>
<td>optimizing transport routes in order to protect the environment</td>
<td>.633</td>
<td></td>
</tr>
<tr>
<td>modernizing transport fleet in order to reduce unnecessary exhaust emissions</td>
<td>.544</td>
<td></td>
</tr>
<tr>
<td><strong>Eigenvalue</strong></td>
<td>2.512</td>
<td>2.272</td>
</tr>
<tr>
<td><strong>% of explained variance</strong></td>
<td>31.399</td>
<td>28.394</td>
</tr>
</tbody>
</table>

Factor *proactivity in greening transport (PGT) in the food retail supply chain* consists of items connected with monitoring CO2 emissions, usage of alternative fuels, usage of information and communication technologies to improve transport route planning, sharing transport resources with other companies. To assess the internal consistency reliability was calculated using Cronbach's \( \alpha \) coefficient, which indicates good reliability of factor *PGT in the food retail supply chain* (\( \alpha = 0.767 \)) and explains 31.399% of the variance.

Factor *reactivity in greening transport (RGT) in the food retail supply chain* consists of items connected with consolidation of transport shipments, better transport utilization, optimisation of transport routes in order to protect the environment and modernisation of transport fleet in order to reduce unnecessary exhaust emissions. To assess the internal consistency reliability was calculated using Cronbach's \( \alpha \) coefficient, which
indicates good reliability of factor \( RGT \) in the food retail supply chain \((\alpha=0.734)\) and explains 28.394% of the variance.

After conducting a factor analysis, ANOVA tests were conducted in order to test the significant differences in greening transport in the food retail supply chain with regard to sample characteristics. **Statistically significant differences in proactivity in greening transport in the food retail supply chain** were found regarding legal form, form of ownership, origin of capital, number of employees and retail formats. Respondents who are more proactive in greening transport in the food retail supply chain are foreign retailers \((F=1.598, p<0.05)\), retailers with foreign form of ownership \((F=2.952, p<0.01)\), retailers with foreign origin of capital \((F=1.948, p<0.05)\), large retail companies (with more than 250 employees; \(F=1.679, p<0.05\)) and retailers that operate in large retail formats, such as supermarkets, hypermarkets \((F=1.583, p<0.01)\). However, **statistically significant differences in reactivity in greening transport in the food retail supply chain** among retailers were found regarding time frame of doing business in the Croatian market and retail formats. Retailers that operate longer on the Croatian market are slower in following new green transport trends \((F=1.892, p<0.05)\), and retailers that operate in neighborhood stores (small retailers; \(F=1.555, p<0.05\)) also.

6. CONCLUSION

Climate change and CO2 emissions are clearly becoming significant factors in logistical decision-making [12]. The environmental issue is one of the key sustainable issues nowadays considered by food retailers. In order to green the supply chain, especially the transport activities, retailers today cooperate and discuss solutions with their suppliers and service providers in order to enhance transport efficiency and to reduce the impact of their transport operations on the environment. This study found that food retailers in Croatia are still passive regarding greening transport activities, because their actions are mainly focused on consolidating transport shipments, better transport utilization, optimizing transport routes while a more active approach toward green transport (such as using ICT to improve transport route planning, sharing transport resources with other companies etc.) is still in its infancy. The common denominator in greening transport in the food retail supply chain is the size of the retailer, where big food retailers are forerunners in showing proactivity in greening the food retail supply chain with regard to small food retailers.

7. REFERENCES


Abstract

Changes in the Croatian economy, introduced upon accession to the European Union occurred, significantly influenced the needs for logistics services, and thus the logistic industry. In planning investments and development of their business, companies mainly rely on their own marketing activities and experience, which are of limited scope, without scientific approach and analysis. For this reason, a systematic research on the current demand for logistics services has been initiated, along with guidelines and projections of further development of the logistics industry in Croatia. The input data for the research were collected through a web survey and from relevant public institutions. The results of the data processing and analysis enable defining elements for formulating projections of further development of the logistics industry in Croatia and defining guidelines for enterprises in making strategic business decisions in the area of logistics. Also a basis of information and knowledge necessary for the improvement of curricula and conducting further research in this area has been created.

Keywords: accession to the EU, logistic services demand, logistic infrastructure, projections

1. INTRODUCTION

Croatia is approaching the first anniversary of the membership in the European Union. Changes in the Croatian economy, introduced upon accession, significantly influenced the needs for logistics services and thus the logistic industry, freight forwarding at the first place. In planning investments and development of their business, companies mainly rely on their own marketing activities and experience, which are of limited scope, without scientific approach and analysis. For this reason, a systematic research of the current demand for logistics services has been initiated, along with guidelines and projections of further development of the logistics industry in Croatia.

This paper is focused on analysing the logistic demand structure in the period since accession and identifying development trends of the logistic industry in Croatia. Conclusions set forth in this paper are based on the research carried out within the project Analysis of logistics services in the Republic of Croatia with guidelines for cooperation with the economy, approved and financed by the University of Zagreb. Input data for the research (facts, knowledge and attitudes about the logistic needs of the Croatian economy) were collected by using available statistical data, case studies of particular logistic solutions and implementation of survey which included the relevant users of logistics services. The survey was performed via Internet, in order to provide a convenient interface for answering the survey questions. Time required for filling out the survey was estimated 20 minutes.

Objectives of the research carried out within the a.m. project and the most important issues to be covered by this paper can be summarized as follows:

- Outlining current structure of the logistic needs, as well as formulating projections of further development of the logistics industry in Croatia;
- Defining guidelines for enterprises in making strategic business decisions in the area of logistics;
- Creating a database of information and knowledge necessary for improvement of curricula and conducting further research in this area.
2. IMPACT OF EUROPEAN INTEGRATIONS TO THE STRUCTURE OF LOGISTIC SERVICES DEMAND IN CROATIAN ECONOMY

It is still too early for an ultimate analysis of the effects to the logistic services demand of the Croatian economy, since Croatia has joined the EU less than a year ago. However, some preliminary assessments should be made, in order to facilitate further research of logistic industry and planning of logistic infrastructure. These assessments could be based on the results of the inquiry outlined in this paper and on the available data and relevant experience from the neighboring countries, Slovenia at the first place.

In this respect, the most important aspects of European integrations affecting the logistic industry in Croatia could be summarized as follows:

- Customs borders with neighboring EU countries have been eliminated, while Croatian border against Serbia, BiH and Monte Negro has become a part of the customs border of the EU;
- Port of Rijeka has become an EU port, i.e. an entry point to the European market;
- Croatia has become a convenient transshipment station for European distribution networks in supplying markets of former Yugoslavian countries.
- Geographical position of Croatia has major importance not only for transit corridors towards the Central European Countries, but also to Baltic (Route 65) and to the rest of former Yugoslavian countries.

In order to analyze the new situation on the market and outline prospective changes in the structure of logistic services demand, the authors have carried out an inquiry among relevant logistic operators and users of logistic services in Croatia. The information acquired refers to the actual traffic in the period of the year 2013 and to the expectations of the examinees. Based on that, the main issues to be taken in consideration are outlined in the following paragraphs.

2.1. Logistic infrastructure

Business expansion on the single European market, with respective increase in the volume of trade flows, provides new opportunities for planning, development and implementation of intermodal transport, which is a standard in developed economies [1], as well as setting up modern customs terminals and cross docking centers at suitable points of transport routes.

By integration into the single EU market, the Port of Rijeka becomes an EU port and the logistics infrastructure in Croatia is gaining importance. Also the market positions previously acquired by global logistic operators will be strengthened up, which will result in further attracting of transit cargo flows. Hence, the need for further development of the Corridor Vb occurs (Figure 1), as well as setting up a modern logistics center & customs terminal in continental Croatia, which could also act as a background terminal of the Port of Rijeka [2].

![Figure 1 – Pan-European transport corridors [3]](image-url)
2.2. Customs operations

The first visible impact of accession to the EU refers to elimination of customs borders against the neighboring European countries, while the Croatian borders against third countries became borders of the EU. It resulted with decrease in number of customs operations, which is expected to correspond with the fact that more than 60% of Croatian foreign trade refers to the EU countries [2]. Also the customs procedures have been greatly simplified by implementing NCTS (New Computerized Transit System), AIS (Automated Import System) and ECS (Export Control System).

Total number of customs declarations related to import and export hasn’t been significantly decreased immediately upon the accession due to the transport & customs procedures started before 1st of July 2013, which therefore needed to be finalized according to the old regulations. At first, it caused traffic jams at the borders against third countries and at the customs terminals, as most of the freight forwarders had already cut down the staff or closed some of their offices. Also the new customs software needed some time to adopt. The situation began to normalize by the end of July 2013. Significant decrease of the number of customs declarations was registered in August and has remained on that level.

Since Croatia holds the part of EU border on its territory, customs operations in transit (NCTS – New Computerized Transit System) over Croatia are to be done at Croatian part of EU border. Also the customs clearance of goods at import from third countries and export to third countries, for any EU country can be done in Croatia. It makes a great difference for international road transport at the first place, but also for combined transport (air – road and sea – road). Major routes of international road transport across Croatian territory are depicted on the Figure 2.

![Figure 2 – Major routes of international road transport across Croatian territory](image)

Croatian economy should benefit from these changes, however the opportunities greatly depend on the available logistic infrastructure and effectivity of the Croatian customs and logistic operators who are expected to speed up the customs procedures.

2.3. Distribution networks

For similar reasons as with the customs operations, distribution centers with customs warehouses have remained busy in the first part of July 2013, but with negative trend started in August. Operations in non bonded warehouses and local delivery/collection operations have remained at the same level.

Customs warehouses are no longer needed for transshipment of goods originated from or destined to EU countries, so the transshipment operations are shifted to non-bonded warehouses. However, there are significant trade flows between the EU and third countries, which could be a substratum for stronger involvement of Croatian logistic infrastructure (ports and inland cargo centers at the first place) into the European distribution networks. It refers mainly to the Port of Rijeka, which has become an entry point to the European market and to a prospective new cargo center near Zagreb [5].
2.4. Intrastat reporting

While the customs procedures in trade with the EU countries were eliminated, another way of control has been implemented. Every entering or arrival of goods from one member country to another or every leaving or dispatch of goods from one member country to another is being reported to Intrastat, a system of collecting statistics on the trade in goods between the member countries of the EU. Intrastat form is a statistical report that contains less data than a custom declaration and is issued on monthly basis (up to 15th for the previous month).

Every company included in the VAT system, whose value of trade in goods with the member countries exceeds the exemption threshold, either for dispatches or arrivals, or for both trade flows, is obliged to declare Intrastat data. Many companies haven’t been included in the system due to relatively high threshold value (1,7 million kn), which was determined based on the simulation data [6] shown in the Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Export</th>
<th>Import</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies involved in foreign trade with EU</td>
<td>22,788</td>
<td>6,945</td>
<td>20,991</td>
</tr>
<tr>
<td>Companies included in Intrastat system</td>
<td>4,289</td>
<td>1,240</td>
<td>3,779</td>
</tr>
<tr>
<td>Percentage share in total number of companies</td>
<td>18,8%</td>
<td>17,9%</td>
<td>18,0%</td>
</tr>
<tr>
<td>Percentage share in total value of trade</td>
<td>97,0%</td>
<td>95,0%</td>
<td></td>
</tr>
</tbody>
</table>

The threshold value has been decreased to 1,2 million kn for the period of 2014, which will include more companies. Intrastat data can also be utilized by the companies that provide data, in analysis and planning of production, purchasing and sales, market research and making strategic business decisions.

3. RESEARCH PLAN

The research involves selecting relevant sources of information, defining a representative sample, determining methods of collecting, processing and analysis of the information, in order to obtain conclusions about the common features and connections between certain categories of the examinees, actual structure of the logistics needs, and projections of the logistic industry development, as outlined in the Figure 3.
Data, knowledge and attitudes about the logistic needs of the Croatian economy were collected by using available statistical data, case studies of particular logistic solutions and implementation of survey which included the relevant users of logistics services, as explained in the following paragraph.

3.1. Development of the survey

The survey was performed on a sample of the first 1,000 firms in Croatia, ranked by the annual sales in international trade. The companies with insignificant logistic needs were excluded that way and the criterion was implemented based on the data provided by the Croatian Financial Agency (FINA) and the Croatian Bureau of Statistics.

In order to achieve the aims of the research, a suitable data base structure was needed, to be used as the substratum. With reference to that, the survey questionnaire was designed to cover the following groups of information:

1. **Company profile** (number of employees, core business, market scope) – information needed for segmentation and categorization of examinees. A sample of user interface (window) for data input is shown on the Figure 4.

   ![Figure 4 – Company profile window](image)

2. **Current logistic needs** (activities, volumes, quality) – information needed for assessment of actual logistic needs of the Croatian economy. The user interface for data input consists of several windows, as partially shown on the Figure 5.

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*Screen shots are displayed. As the survey is designed for Croatian companies, the questions are in Croatian language (there is no English version).*
3. **Current logistic solutions and level of satisfaction** (internal resources, outsourcing, partial outsourcing) – information needed for assessment of current potential of the logistic market. The input data related to the implemented logistic solution are entered via several windows, like the one shown on the Figure 6, while the data related to the level of satisfaction with the implemented solutions are entered via the windows shown on the Figure 5. Each window refers to the respective logistic activity, such as customs clearance, intrastate reporting, different modes of transport, warehouse operations, etc.

4. **Prospective logistic needs and desirable solutions** – information needed for forecasting and determining development trends in logistic industry. The input data are entered via several different windows, related to the respective logistic activities, as partially shown on the Figure 7.

The tool used to design the questionnaire and carry out the survey was Lime Survey, an open source online survey application written in PHP (Hypertext Preprocessor – a server-side scripting language designed for web development) based on SQL (Structured Query Language) database and hosted by the University Computing Centre (SRCE).

It enables automated sending of invitations, reminders and tokens by email, as well as exporting data in various formats: text, CSV (Comma Separated Value), PDF (Portable Document Format), SPSS (Statistical Package for Social Studies), R (programming language for statistics), queXML (questionnaire toolkit, Extensible Markup Language) and Microsoft Excel, which was essential for realization of the survey.
3.2. Data processing methods

Although a number of routines for basic statistical and graphical analysis are available within the Lime Survey, the survey data were exported in Excel format, in order to utilize some more advanced features included in the Excel Analysis ToolPak, such as:

- **Descriptive statistics** – providing information about the central tendency and variability of the data, in order to determine an average profile of current logistic services demand and to identify expectations of the examinees.
- **Ranks and percentiles** – defining the ordinal and percentage rank of each value in a data set in order to analyze the relative standing of values in the data set, in order to outline the survey sample structure and to quantify proportional representation of a particular logistic solution.
- **Regression analysis** – analyzing how a single dependent variable is affected by the values of one or more independent variables, in order to identify a development trend. The method is used to predict development trends of the logistic industry in Croatia, i.e. prospective structure of the logistic services demand.

Selected results of the survey data processing (only the most relevant for this paper) are briefly outlined in the following paragraph.

4. OUTLINE OF THE LOGISTIC SERVICES DEMAND STRUCTURE

In order to get a representative survey sample, various companies were included, from micro enterprises to big enterprises, food and non-food sector, in production and commerce business. The conclusions regarding current and prospective structure of the logistic services demand were mainly based on analysis of current logistic solutions implemented by the examinees and respective level of satisfaction, prospective logistic needs of the examinees and desirable solutions, scale of logistic services used.

4.1. Segmentation of the survey sample

Segmentation of the survey sample (companies that responded to the survey) is defined according to company profile. Implemented criteria and respective percentage share are listed below:

1. **Main criteria: Core business**
   - Production: 45%
   - Commerce: 55%

Sub criteria: Food/Non-Food, Wholesale/Retail/Both
2. Main criteria: Number of employees
   - Micro Enterprise; up to 10 employees: 7%
   - Small Enterprise; 11 to 50 employees: 31%
   - Middle Enterprise; 51 to 250 employees: 29%
   - Big Enterprise; 251 and more employees: 33%

4.2. Results of the survey data analysis

Current logistic needs, logistic solutions implemented and respective level of satisfaction were analyzed for the following logistic operations, as well as prospective logistic needs in the following two years period indicated by the examinees:

- Customs clearance;
- Intrastat reporting;
- Maritime transport (FCL/LCL separately);
- Waterway transport (containerized/non-containerized cargo separately);
- Air freight;
- Rail transport;
- Road transport (international/local and FTL/LTL separately);
- Courier service (international/local and docs/packages/pallets separately);
- Warehousing (bonded/non-bonded, warehouse space and basic operations/VAS separately).

Outlining full scale results of the data analysis would exceed the work frame of this paper, so two representative logistic operations, customs clearance and warehousing, were sorted out to illustrate the results of the survey data analysis.

Percentage share of a particular logistic solution, level of satisfaction with the implemented logistic solution and expectations for the following two years period (import and export separately) regarding the customs clearance are outlined in the Figure 8.

**Figure 8** – Customs clearance operations

Percentage share of a particular logistic solution for warehouse operations (basic), level of satisfaction with the implemented logistic solution and expectations for the following two years period regarding the warehouse space are outlined in the Figure 9.
4.3. Scale of logistic services usage

Logistic outsourcing break down against frequency of a particular logistic service usage is outlined in the Figure 10. The examinees were also asked to indicate which logistic services they get from a single operator, as well as about their preferable solution regarding logistic outsourcing.

With reference to the logistic outsourcing, majority of the examinees (73%) answered they would prefer an integrated logistic solution, i.e. package of complementary logistic services with a single point of contact, instead of different operators providing particular logistic services.

4.4. Integration of logistic services

Fourth-party logistics providers, abbreviated 4PL, are consulting firms offering logistics consulting, transportation and supply chain management services. A fourth party logistics provider (4PL) is an independent, singularly accountable, non asset based integrator who assembles the resources, capabilities and technology of its own organization and other organizations, including 3PLs and 2PLs, to design, build and run comprehensive supply chain solutions for clients. They are different from the lower three levels: 3PL, 2PL that are actual operators/carriers, and 1PL that are final users (Figure11).
Integrating and coordinating logistic operations within the structure of the supply chain can be frustrating and time consuming. Suppliers shipping dates, executing and changing orders, giving instructions to carriers, consolidators or 3PLs are just some of the challenges dealt with. It is a great opportunity for 4PLs to develop their business [7].

![Figure 11 – Integration of logistic providers into the supply chain [8]](image)

5. CONCLUSION

Results of the research primary reflect the recent changes in the structure of logistic services demand in the Croatian economy. Comparing to the situation prior to accession to the European Union, users of logistic services tend not to fully define logistic solutions, but to extensively exploit the know – how and resources of logistic operators. They prefer an integrated logistic solution, i.e. package of complementary logistic services with a single point of contact, instead of different operators providing particular logistic services.

Logistic operators are expected to participate in defining the supply chain strategy and to provide for a suitable integrated package of logistic services, hence it makes logistic operator responsible for the outcome (results), instead of their performance. Integration into the single European market yields some new business opportunities for Croatian logistic operators which mainly refer to the providing 4PL services, an emerging business segment on the integrated European market.

Upgrading their competences and expertise towards 4PL segment would require the logistic operators to make additional efforts in professional education and training of staff. A closer cooperation with educational institutions in the field of traffic and transport engineering could successfully facilitate such efforts, in order to improve their market position.

It is a good opportunity for logistics operators in Croatia, to improve their business portfolio by adopting more advanced logistics services developed according to the guidelines outlined in this paper.

6. REFERENCES

A MODEL OF CLOSED-LOOP GREEN SUPPLY CHAIN LOGISTICS WITH UNCERTAIN REVERSE PARAMETERS

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Abstract

Due to the problem on global warming, green supply chain management, in particular, logistics, has drawn the attention of researchers. Although there were closed-loop green logistics models appeared in the literature, most of them did not consider the uncertain environment in general terms. In this study, a generalized model was proposed when the uncertainty is expressed by fuzzy and interval numbers. A solution procedure was developed. The resultant solution provides useful information of the expected solution under a confidence level.

Keywords: fuzzy number, interval programming, green supply chain, mean and variance

1. INTRODUCTION

The green supply chain (GSC) comprises two parts: forward supply chain and reverse supply chain. Apart from the conventional supply chain, GSC has an additional role called dismantlers, which allow green logistics to operate with additional functions of recovery and recycling. Schultmann et al. (2006), Baumgarten et al. (2003), and Lu Q. et al. (2000) have discussed this issue in detail. Wang and Hsu (2007a and b) evaluated the GSC closed-loop model based on the Conservation Law of operation units so that no material will be wasted through recycling and recovery. By extending the traditional supply chain into a supply “loop”, at a stable state of operation, there will be no specific depot or destination for each operation unit along the green supply chain.

Kongar Elif (2004) discussed the difference between forward and reverse supply chain (TABLE I) and mention that reverse supply chain is harder to forecast. Ovidiu Listes (2007) and Salema. et al. (2007) also focused on the uncertainty in reverse logistics, but Ovidiu Listes is not an optimal based model and both Ovidiu Listes and Salema et al. evaluated the model by special scenarios with less generality. Biehl et al. (2007) used experiment design to analyze the uncertain impacts of the reverse logistics and noted that unlike forward logistics, reverse logistics operations are complex and prone to a high degree of uncertainty from collection rates-landfilling rates, the availability of recycled production inputs, and capacities in the reverse channel.

<table>
<thead>
<tr>
<th>Supply Chain</th>
<th>Reverse Supply Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easier to forecast</td>
<td>Harder to forecast</td>
</tr>
<tr>
<td>Profit benefit orientated</td>
<td>Environmentally benign product benefit orientated</td>
</tr>
<tr>
<td>Distribution to multiple locations from a single source</td>
<td>Distribution to a single location from multiple sources</td>
</tr>
<tr>
<td>Stable product quality</td>
<td>Unstable product quality</td>
</tr>
<tr>
<td>Stable product packaging</td>
<td>Unstable product packaging</td>
</tr>
<tr>
<td>Stable product structure</td>
<td>Unstable product structure</td>
</tr>
<tr>
<td>Route of distribution is known/determined</td>
<td>Route of distribution is unknown/undetermined</td>
</tr>
<tr>
<td>Known main characteristics</td>
<td>Unknown main characteristics</td>
</tr>
<tr>
<td>More or less stable pricing</td>
<td>Pricing is affected by various factors/less stable</td>
</tr>
<tr>
<td>Speed is important</td>
<td>Speed is not a factor</td>
</tr>
<tr>
<td>Easily visualized cost factors</td>
<td>Hard to determine the cost</td>
</tr>
<tr>
<td>Stable inventory management</td>
<td>Unstable inventory management</td>
</tr>
<tr>
<td>Manageable product life cycle</td>
<td>More complicated product life cycle</td>
</tr>
<tr>
<td>Well known marketing techniques</td>
<td>Marketing techniques involve more complicated factors</td>
</tr>
<tr>
<td>Clearly observed processes</td>
<td>Less visible processes</td>
</tr>
</tbody>
</table>
In this paper, we base on Wang and Hsu’s model and consider the uncertain environment along reverse logistics. We focus on the main uncertain factors of recovery rate, customer demand and landfilling rate so that a more realistic logistics plan, can be developed to support a decision for distribution centers for capacities percentage in the reverse channel. In order to make the model more generality, we use the membership function of fuzzy to present the uncertain information, and then transfer the membership function through all level-cuts to a crisp interval by possibilistic mean. This way can consider all fuzzy information and make an easier and crisper decision for decision maker.

After introducing the mathematical programming of green supply chain logistics in Section 2, the literatures about possibilistic mean interval and variance of fuzzy number and a solution of interval programming after transferring fuzzy numbers into interval numbers will be proposed with specification in Section 3. Finally, in Section 4, the conclusion will be drawn..

2. PROPOSED MATHEMATICAL MODEL

In a multistage supply chain network problem, Wang and Hsu (2007a and b) and Yeh (2005) have suggested the following conditions which should be satisfied in modeling.

a. The demand of each customer must be satisfied
b. The flow is only allowed to be transferred between two consecutive stages
c. The number of facilities that can be opened and their capacities are both limited

When customer demand, recycling rate, and landfill rate are uncertain, we are going to develop a mathematical programming model with the notations defined below:

**Parameters:**

- \( a_i \): Capacity of supplier, \( i = 1, 2, \ldots, I \)
- \( b_j \): Capacity of manufactory, \( j = 1, 2, \ldots, J \)
- \( S_k \): Capacity of the DC, \( k = 1, 2, \ldots, K \)
- \( pc_j \): Uncertain recovery percentage of customer, \( l = 1, 2, \ldots, L \)
- \( pl_m \): The uncertain landfilling rate of dismantler, \( m = 1, 2, \ldots, M \)
- \( \tilde{d}_i \): Uncertain demand of the customer
- \( e_k \): Capacity of dismantler
- \( s_j \): Unit cost of production in manufactory using raw materials from supplier
- \( t_m \): Unit cost of transportation from each manufactory to each DC
- \( u_k \): Unit cost of transportation from DC to customer
- \( v_m \): Unit cost of transportation from DC to dismantler
- \( w_m \): Unit cost of transportation from dismantler to manufactory
- \( Rd_m \): Unit cost of recovery in DC from customer
- \( f_j \): Fixed cost for operating Manufactory
- \( g_k \): Fixed cost for operating DC
- \( h_m \): Fixed cost for operating dismantler
- \( \phi \): Fixed cost for landfilling per unit.

**Variables:**

- \( x_j \): Quantity produced at manufactory using raw materials from supply
- \( y_{jk} \): Amount shipped from manufactory to DC
- \( z_m \): Amount shipped from DC to customer
- \( a_m \): Amount shipped from dismantler to manufactory
- \( Rd_m \): Amount shipped from DC to dismantler
- \( RSC_k \): Recovery capacity of the DC
- \( \alpha_j \): if production takes place at manufactory
- \( \beta_k \): if DC is opened
- \( \delta_m \): if dismantler is opened

Object function:

Subject to:
Model:

Object function:

\[
\min \quad \hat{TC} = \sum_{i} \sum_{j} s_{ij} x_{ij} + \sum_{j} \sum_{k} t_{jk} y_{jk} + \sum_{k} \sum_{l} u_{kl} z_{kl} \\
+ \sum_{k} \sum_{m} v_{km} o_{km} + \sum_{j} \sum_{m} w_{jm} R_{jm} + \sum_{k} R_{ku} R_{zk} \\
+ \sum_{j} f_{i} \alpha_{j} + \sum_{k} g_{i} \beta_{k} + \sum_{m} h_{k} \delta_{m} + \phi \sum_{j} p_{i} o_{jm} 
\]

\( (1) \)

Subject to:

\[ \sum_{j} x_{ij} \leq a_{i}, \quad \text{for all } i \]  \( (2) \)

\[ \sum_{k} y_{jk} - b_{j} \alpha_{j} \leq 0, \quad \text{for all } j \]  \( (3) \)

\[ \sum_{j} x_{ij} + \sum_{m} R_{km} - \sum_{k} y_{jk} = 0, \quad \text{for all } j \]  \( (4) \)

\[ \sum_{k} z_{kl} + \sum_{m} o_{km} - Sc_{k} \delta_{k} \leq 0, \quad \text{for all } k \]  \( (5) \)

\[ \sum_{k} y_{kj} - \sum_{l} z_{kl} = 0, \quad \text{for all } k \]  \( (6) \)

\[ RSC_{k} - Pd_{k} Sc_{k} = 0, \quad \text{for all } k \]  \( (7) \)

\[ \sum_{m} o_{km} - RSC_{k} \beta_{k} \leq 0, \quad \text{for all } k \]  \( (8) \)

\[ \sum_{k} R_{z_{km}} - \sum_{m} o_{km} = 0, \quad \text{for all } k \]  \( (9) \)

\[ \sum_{k} R_{z_{km}} - \bar{p}_{k} \sum_{l} z_{kl} \geq 0, \quad \text{for all } l \]  \( (10) \)

\[ \sum_{l} z_{kl} \geq \tilde{d}_{l}, \quad \text{for all } l \]  \( (11) \)

\[ \sum_{k} R_{d_{km}} + \bar{p}_{k} \sum_{m} o_{km} - e_{k} \delta_{k} \leq 0, \quad \text{for all } m \]  \( (12) \)

\[ \sum_{m} o_{km} - \sum_{k} R_{d_{km}} - \bar{p}_{k} \sum_{m} o_{km} = 0, \quad \text{for all } m \]  \( (13) \)

\[ \alpha_{i}, \beta_{j}, \delta_{k} = \{0, 1\}, \quad \text{for all } j, k, m \]  \( (14) \)

\[ x_{ij}, y_{jk}, z_{kl}, o_{km}, R_{km}, R_{z_{km}}, RSC_{k}, Pd_{k}, \in N \cup \{0\} \]

\( \forall i, j, k, l, m \)  \( (15) \)

3. RESOLUTION OF UNCERTAINTY

3.1 Possibilistic Mean Interval and Variance of Fuzzy Number

Dubois and Prade (1987) defined an interval-valued expectation of fuzzy number, viewing them as consonant random sets. Carlsson C. and Robert F. (2001) introduced the notations of lower possibilistic and upper possibilistic mean values, the interval-valued possibilistic mean, of a continuous possibility distribution, which are consistent with Extension Principle (Zadeh, 1975) and with well-known definition of expectation in probability theory.

A γ-level set of a fuzzy number A is defined by \([A]_{\gamma} = \{ t \in R | A(t) \geq \gamma, 0 \leq \gamma \leq 1 \} \). Carlsson C. and Robert F. (2001) use Goetschel and Voxman’s (1986) method for ranking fuzzy number as

\[ A \leq B \Leftrightarrow \int_{\gamma} \gamma [a_{l}(\gamma) + a_{u}(\gamma)]d\gamma \leq \int_{\gamma} \gamma [b_{l}(\gamma) + b_{u}(\gamma)]d\gamma \]  \( (15) \)
This is a concept of area, and by the definition of Carlsson C. and Robert F. (2001), the possibilistic mean value of fuzzy number is

\[
\overline{M}(A) = \int_{0}^{1} \gamma [a_{L}(\gamma) + a_{U}(\gamma)] d\gamma = \int_{0}^{1} \gamma [a_{L}(\gamma) + a_{U}(\gamma)]/2d\gamma \\
= \frac{1}{2} \left( \int_{0}^{1} \gamma a_{L}(\gamma) d\gamma + \int_{0}^{1} \gamma a_{U}(\gamma) d\gamma \right)
\]

(16)

and \( \overline{M}(A) \) is the arithmetic means of all \( \gamma \)-level sets.

The lower and upper possibilistic mean value of \( A \), \( M_{L}(A) \) and \( M^{*}(A) \), are

\[
M_{L}(A) = 2 \int_{0}^{1} \gamma a_{L}(\gamma) d\gamma = \frac{1}{2} \left( \int_{0}^{1} \gamma a_{L}(\gamma) d\gamma \right)
\]

and \( M^{*}(A) = 2 \int_{0}^{1} \gamma a_{U}(\gamma) d\gamma = \frac{1}{2} \left( \int_{0}^{1} \gamma a_{U}(\gamma) d\gamma \right) \) .

(17)

\( M_{L}(A) \) and \( M^{*}(A) \) are the lower and upper possibility-weighted average of the minima and maxima of \( \gamma \)-level sets, respectively.

\( M(A) = [M_{L}(A), M^{*}(A)] \) is a closed interval bounded by the lower and upper possibilistic mean values of \( A \).

Then, we also can define the variance as follows by Carlsson C. and Robert F. (2001).

\[
Var(A) = \int_{0}^{1} \gamma [\left( \frac{a_{L}(\gamma) + a_{U}(\gamma)}{2} - a_{L}(\gamma) \right)^{2} + \left( \frac{a_{L}(\gamma) + a_{U}(\gamma)}{2} - a_{U}(\gamma) \right)^{2}] d\gamma
\]

\[
= \frac{1}{2} \left( \int_{0}^{1} \gamma (a_{L}(\gamma) - a_{U}(\gamma))^{2} d\gamma \right)
\]

(18)

The variance of \( A \) is defined as the expected value of the squared deviations between the arithmetic mean and the endpoints of its level sets, i.e. the lower possibility-weighted average of the squared distance between the left-hand endpoint and the arithmetic mean of the endpoints of its level sets plus the upper possibility-weighted average of the squared distance between the right-hand endpoint and the arithmetic mean of the endpoints of its level sets.

After this possibilistic process, we can transfer membership function of fuzzy number into a crisp integer number through all possible level cuts. Then, solving a fuzzy mathematical model is equivalent to solving an ordinary integer programming model with addition information of the confidence interval in making a decision.

### 3.2 The Solution of Interval Programming

Interval \( A \) is alternatively represented as \( A = <m(A), w(A)> \) where, \( m(A) \) and \( w(A) \) are the mid-point and half-width (or simply as ´spread´) of interval \( A \), i.e.,

\[
m(A) = \frac{1}{2} (a_{L} + a_{U}) , \ w(A) = \frac{1}{2} (a_{U} - a_{L})
\]

(19)

Let \( A = [a_{L}, a_{U}] \), \( B = [b_{L}, b_{U}] \) and \( x \) is a singleton variable.

By Sengupta A. et al (2001), they defined the acceptance function to solve the interval programming. \( \phi : I \times I \rightarrow \{0, \infty\} \) such that \( \phi(A < B) \) or \( \phi(A, B) \),
\[
\phi(A < B) = \frac{(m(B) - m(A))}{(w(B) + w(A))},
\]

(20)

where \( w(B) + w(A) \neq 0 \). \( \phi(A < B) \) may be interpreted as the grade of acceptability of the ‘first interval to be inferior to the second interval’.

The grade of acceptability of \( A \leq B \) may be classified and interpreted further on the basis of comparative position of mean and spread of interval \( B \) with respect to those of interval \( A \) as follow:

\[
\phi(A < B) = \begin{cases} 
0, & \text{if } m(A) = m(B), \\
> 0, & \text{if } m(A) < m(B) \\
\geq 1, & \text{if } m(A) < m(B) \text{ and } a_i \leq b_i 
\end{cases}
\]

(21)

According to \( \phi \) -index the acceptability condition of \( Ax \leq B \) may be defined as \( \phi(Ax < B) \geq 0 \), i.e. \( m(Ax) \leq m(B) \). There may have two different possible setups.

Case-I: When interval \( A \) is relatively narrower than interval \( B \): \( Ax \) may be nested in \( B \). For example, for \( x = 2 \), the relation \([2, 4] \leq [2, 10] \) may be viewed as given in Fig. 1.

---

**Figure. 1 INTERVAL \( Ax \) RELATIVELY NARROW THAN INTERVAL \( B \)**

---

Case-II: When interval \( A \) is relatively wider than it was in case I: \( B \) may be nested in \( Ax \). For example, for \( x = 2 \), the relation \([0, 6] \leq [2, 10] \) may be viewed as shown in Fig. 2.

---

**Figure. 2 INTERVAL \( Ax \) RELATIVELY WIDER THAN INTERVAL \( B \)**

---

From the examples given above, for both of the cases, the following remarks may be made:

(i) Case I definitely satisfies the original interval inequality for \( x \leq 2 \) because \( \phi(Ax < B) \geq 0 \). However, an optimistic DM may remain under-satisfied with the optimal constraint condition and for getting higher satisfaction, he may like to increase the value of \( x \) to such an extent that \( \phi(B < Ax) \) does not pass over a threshold assumed and fixed by him. On the other hand, the pessimistic DM may want to control the \( \phi(Ax < B) \) to be a higher value.

(ii) On the other hand, by case II, the original interval inequality condition is not denied even for \( x \leq 2 \) because \( \phi(Ax < B) \geq 0 \). But a pessimistic DM may not be satisfied if the right limit of \( Ax \) spills over the right limit of \( B \). To attain his required level of satisfaction the DM may even like to reduce the value of \( x \) so that \( a_i \leq b_i \).

Sengupta A. et al (2001) also mentioned that one's possible reaction is as much as similar to Moore's concept of set-inclusion, i.e.,

\[\begin{align*}
Ax \leq B & \text{ let } Ax \subset D \text{ where } D = [-\infty, b_i]. \\
Ax \geq B & \text{ let } Ax \subset D \text{ where } D = [b_i, \infty].
\end{align*}\]

**Lemma 1: (Moore, 1979)**

If an optimal solution does not satisfy the binding condition and if there are alternative optimal solutions, some of them may be dominated alternatives to the original model.
Keeping in view the two remarks stated above and the Moore's concept, Sengupta A. et al proposed a satisfactory crisp equivalent form of interval inequality relation as follows:

\[
Ax \leq B \Rightarrow \begin{cases} 
  a_i x \leq b_i, \\
  \phi(B < Ax) \leq \theta \in [-1,1], 
\end{cases} \tag{22}
\]

where, \( \theta \) may be interpreted as an optimistic threshold assumed and fixed by the DM. For the meaning, the lower bound of \( Ax \) is more close to the upper bound of \( B \) when \( \theta \) is increase, but limit by \( a_L x \leq b_U \). By the result, the upper bound of \( Ax \) will never exceed the upper bound of \( B \) even \( \theta \) equal to 1.

In the same way, for \( Ax \geq B \), we have the satisfactory crisp equivalent form by the following pair:

\[
Ax \geq B \Rightarrow \begin{cases} 
  a_i x \geq b_i, \\
  \phi(Ax < B) \leq \theta \in [-1,1] 
\end{cases} \tag{23}
\]

Similarity, the upper bound of \( Ax \) is more close to the lower bound of \( B \) when \( \theta \) is increase, but limit by \( a_L x \geq b_L \). By the result, the lower bound of \( Ax \) will never lower than the lower bound of \( B \) even \( \theta \) equal to 1.

In conclusion, by Moore’s concept, \( a_U x \leq b_U \) and \( a_L x \geq b_L \) confirm that the constraints’ upper bound is less than the RHS’ or the constraints’ lower bound is greater than the RHS’, respectively. The method’s goal is to control the solution that makes \( Ax \leq B \), the upper bound of interval \( Ax \) is as close as possible to the upper bound of interval \( B \), and \( Ax \geq B \), the lower bound of interval \( Ax \) is as close as possible to the lower bound of interval \( B \). If \( \theta = -1 \), it’s the worst pessimistic think for DM, and else if \( \theta = 1 \) then it’s the best optimistic think for DM.

4. CONCLUSION

Green issues have become more and more important in recent years. The GSC is a very complexity and uncertain environment, and the logistics planning for DM is harder than before. Different kind of DMs in an uncertain environment may have different choice. An optimistic DM may want to increase the \( \theta \) to get a higher possible goal, even the risk is more. The pessimistic DM may want to decrease \( \theta \) to get a lower risk.

However, we provided the results to a DM to choose, and also we provided the confidence interval to say the possibility of the objective range. The DM can use the expected interval goal of fuzzy number and the variance to get a confidence interval under \( \theta \) they used, and they can also understand the expected interval and confidence interval by their choice. In the end, the must be evaluated by themselves, and the \( \theta \) with risk of violated constraints is another issue that can be considered.

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5. REFERENCES


STOCHASTIC TIMED PETRI NETS FOR PRODUCTION PROCESS SIMULATION AND ASSESSMENT

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Abstract

Stochastic timed Petri net modelling language is a powerful tool for the event driven uncertain process simulation. The present paper applies such a tool to the industrial context revising a stepwise approach to support practitioners in the design and dynamic simulation of the manufacturing and assembly activities. An application based on a semi-automatic assembly line is, further, presented to exemplify the approach use and to demonstrate its flexibility and strengths. The stochastic timed Petri net model for the industrial scenario is described together with the simulation outcomes of interest for the assembly line design and the activity scheduling.

Keywords: stochastic timed Petri net, industrial system, dynamic simulation, resource planning, assembly.

1. INTRODUCTION

The complexity of products, their customisation to meet the client expectations together with the challenges coming from the market arena force all the companies to make continuous efforts for the design and optimisation of their industrial processes, to join quality efficiency targets to low production costs [1].

Among the industrial activities, manufacturing and assembly are known as high value processes able to significantly add value to the final products [2]. In parallel, such industrial processes require to integrate multiple resources, e.g. single machines, workstations, human labour, devices and auxiliary plants, etc., to meet the target production levels, in term of mix and quantity, matching the market demand profile. Such resources are a crucial asset for all the companies, due to the associated annual operating costs and the long-term investments for purchase, maintenance and replacement [3].

The study of effective approaches to optimise the aforementioned industrial processes is a hot topic for both researchers and practitioners of the industrial sector. Strategies, qualitative and quantitative methods facing this issue from different viewpoints, e.g. single vs. multi-objective planning, static vs. dynamic design, system analysis vs. simulation, are proposed by the literature in the past years together with a large set of useful tools and programming languages to model the operative systems [4].

Among the existing modelling languages, Petri nets, firstly introduced by C.A. Petri in 1962 [5] to synchronise communicating automata, are a well-known and powerful event-driven modelling language to represent complex and dynamic environments. Due to the origin of such a language, the ICT and the telecommunication sectors are the natural contexts for the Petri net based applications. On the contrary, minor attention is paid to the study of the potential of adopting this language to the industrial sector to support the validation and dynamic simulation of manufacturing and assembly processes. Particularly, the standard literature is far from outlining a general approach suited for applications in multiple instances and scenarios.

This paper faces this lack focusing on stochastic timed Petri nets, i.e. Petri nets including statistic distributions for the timed transitions, with the aim to propose a general and systematic approach for their adoption during the industrial process simulation and assessment. Close to the method discussion, a realistic
case study modelling a semi-automatic assembly process is focused to both discuss the approach applicability and revise the potential advantages during the decision making process.

According to the introduced topic, the reminder of this paper is organized as follows: the next Section 2 revises the literature on Petri nets, and stochastic timed Petri nets, with deep focus on their application to the industrial sector. Key fundamentals are, further, provided. Section 3 outlines the steps of the proposed approach to support the design of industrial processes, while Section 4 introduces the aforementioned realistic case study taken from the semi-automatic assembly industry. The case study process simulation outcomes, driving the performance assessment phase, are fully described in Section 5 before drawing the paper conclusions together with suggestions for future developments in the last Section 6.

2. FUNDAMENTALS AND LITERATURE REVIEW

Petri net fundamentals are in a wide range of literature contributions and several authors review the application of Petri net language to the analysis of controllers for discrete event systems [6,7].

2.1 Petri net language

Basically, a Petri net structure is a tuple:

\[ N_s = \langle P, T, A, \omega \rangle \]  

where \( P = \{ p_1, ..., p_i, ..., p_j \} \) is the set of places, \( T = \{ t_1, ..., t_j, ..., t_{|T|} \} \) is the set of transitions, with \( P \cap T = \emptyset \), \( A \subseteq (P \times T) \cup (T \times P) \) is the set of arches defining a flow relationship between places and transitions and vice versa and \( \omega : A \rightarrow \mathbb{N}^+ \) is the so-called weight function associating an integer positive value to each arch.

Given a Petri net structure, \( N_s \), the current state of a Petri net is univocally identified by a marking \( X \), defined through the marking function \( x : P \rightarrow \mathbb{N}^+ \) that associates an integer number of tokens to each place, \( x(p_i) \). Consequently, a Petri net is defined as follows:

\[ N = \langle N_s, X \rangle = \langle P, T, A, \omega, X \rangle \]  

The dynamic evolution of Petri nets is based on the concepts of enabled and fired transitions. A generic transition, \( t_j \), is enabled if all places entering it have a number of tokens \( x(p_j) \) not lower than the weight of the arches between the places and the transition. Given a marking \( X \), all the enabled transitions are fireable. Firing a transition means generating a dynamic evolution of the net. Particularly, when a specific transition \( t_j \) is fired all the places entering it are decreased of a number of tokens equal to the weight of the correspondent arch, while all the places exiting the transition are increased of a number of tokens equal to the weight of the correspondent arch. After each firing, a new marking \( X' \) of the Petri net is reached. In the beginning, the current net marking is called initial marking \( X_0 \).

Timed Petri nets, and stochastic timed Petri nets introduce the time dependence to the aforementioned language. In this context transition-timed Petri nets are considered, only. Formally, a clock structure \( \mathcal{V} \) is introduced. It associates a temporal delay, \( \nu(t_j) \), to each transition \( t_j \). Consequently, when the transition \( t_j \) is enabled it becomes fireable after \( \nu(t_j) \) time units. The clock structure introduces a temporal delay to all transitions having \( \nu(t_j) > 0 \), i.e. timed transitions. Furthermore, the clock structure and the related temporal delay can be both deterministic or stochastic, so that \( \nu(t_j) \) is a fixed value or it ranges according to a defined probability distribution.

Thus, the stochastic timed Petri nets, adopted in the following, are formally defined as in Equation 3.

\[ STN = \langle N, \mathcal{V} \rangle = \langle N_s, X, \mathcal{V} \rangle = \langle P, T, A, \omega, X, \mathcal{V} \rangle \]  

2.2 Petri net industrial application review

The following Table 1 shortly revises a set of literature contributions about the application of Petri nets to the industrial sector. Classifications by the faced topic and the adopted language are introduced.
Table 1 – Petri net industrial applications, key literature review

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<th>Production</th>
<th>Scheduling</th>
<th>Maintenance</th>
<th>Un-timed</th>
<th>Timed</th>
<th>Stochastic timed</th>
<th>Ref.</th>
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Among the industrial issues, the simulation and assessment of production systems, e.g. flow shops, assembly lines, flexible manufacturing and assembly systems, etc., are the most frequently debated topics. Furthermore, the standard literature faces the modelling phase adopting deterministic timed Petri nets and neglecting the uncertainty in the activity duration, i.e. all the timed transitions are with a deterministic delay. Such a modelling assumption is realistic and acceptable for automatic systems. On the contrary, in presence of semi-automatic or manual working phases the uncertainty introduced by the human behaviour suggests to adopt stochastic approaches. Nevertheless, this aspect is frequently neglected by the literature. Only two recent contributions adopt stochastic timed Petri nets to model uncertainty in the industrial processes. Zhou et al. [8] face the buffer modelling in automated manufacturing systems, while Tüysüz et al. [19] adopt stochastic Petri nets to model a flexible manufacturing cell. Following the potential advantages coming from a stochastic perspective, i.e. the increase of the language reliability, the effectiveness of the simulation outcomes, etc., the next Section 3 presents a stepwise approach to support practitioners in the design and dynamic simulation of production processes, while Section 4 applies it to a semi-automatic assembly line. Furthermore, next to the assembly line modelling, the working activities and machine failures and maintenance phases are considered joining together three topics that are often studied independently.

3. STEPWISE APPROACH DEFINITION

An industrial process uses several resources working together to manufacture, assemble, inspect, etc., a product or a product mix.

A general reference stepwise approach of help to build a stochastic timed Petri net language, modelling the industrial system behaviour and of help for its dynamic simulation and assessment, is in Figure 1.

![Figure 1 – Stepwise approach for stochastic timed Petri net modelling](image)

Process data mining goal is to provide a quantitative description of the process. Key data to collect and focus on are about the product working cycles and processing times, the required resources (number and reliability profiles), the existence of queues and/or buffers and their capacity limits, the work shift structure, the productivity goals to meet, etc. From such data the modelling process starts.

The modelling strategy selection, i.e. the second step, chooses the best approach to follow. Three basic strategies are possible.
- Resource based/physical strategy. The focus is on the system components classified as resources, i.e. working elements, or queues/buffers, i.e. waiting elements. Products flow through the resources to complete their working cycles.
- Process based/functional strategy. The work cycles and process phases define the structure of the net, while, the resources are shared among the phases.
- Hybrid strategy. A mix of the previous two strategies is used.

This phase is driven by the available data, the complexity of the process to represent, i.e. the higher the process complexity, the higher the functional strategy best fits, the overall assessment purposes and, finally, the experience of the net developer.

During the atomic subnet study, according to the selected strategy, several atomic subnets are built, independently, representing the elements and phases of the system. Examples of typical atomic subnets useful in the industrial practise are in Figure 2. They are adopted in the following case study.

**Figure 2** – Atomic subnets of industrial interest, (a) resource, (b) finite buffer, (c) infinite buffer, (d) queue

The simulation phase starts with the integration of the atomic subnets to create the process model. Typical aspects to face refer to:
- The working cycle modelling, faced creating ordered sequences of atomic phases with intermediate buffers and/or queues.
- The shared resource allocation, faced introducing conflict structures among all the phases requiring the same resource, i.e. resource allocation to a phase forces the others to wait its release, in a buffer or a queue.
- The machine maintenance profile modelling, faced through the inclusion of stochastic time to failure (time to repair) transitions blocking (releasing) the failed (repaired) resource.
- The parallel activity synchronisation, faced through independent nets feeding a unique scheduling structure setting the cycle time.

Furthermore, the initial marking, $X_0$, generally assumes all the resources available, no work-in-progress (WIP) and sets the origin of simulation time at the beginning of the working day. Other assumptions impact on the initial phase, only, and not on the long-term behaviour of the net. Furthermore, the simulation length is defined by the occurrence of at least one of these conditions:
- Reach of a time limit.
- Deadlock marking condition occurrence.

The simulation report, including the ordered sequence of the reached marking states and the correspondent simulation time, represents the key outcome driving the process analysis. It allows to study the stochastic timed Petri net evolution, suggesting dynamic information profiles about working times, delays, required resources, buffer and queue dimensions, critic phases, etc. These evidences are the key elements driving the final step about drawing actions and feedbacks to improve the industrial process.

An application of the proposed approach is in the following case study.
4. INDUSTRIAL CASE STUDY

Figure 3 depicts the circular conveyor adopted by an Italian company of the industrial white good sector to assembly the low-complexity, high-volume, medium-size mechatronic controllers to be installed on several devices and machines (Figure 4).

![Figure 3 – Assembly line structure, resources, buffers and queues](image1)

![Figure 4 – Mechatronic controller to assembly](image2)

The motorised roller conveyor dimensions are of 15×7m and its average speed is of 0.5m/s. Raw components to assembly, i.e. the motherboard, the lower and the upper cases, enter the process through the Op1 manual resource, that picks from the input buffer and places onto the 0.53×0.37m pallets, circularly flowing in the system. The empty pallets wait to be used onto the conveyor section called Queue-A.

Parts flow the system reaching the Selective Compliance Articulated Robot Arm (SCARA) R1 for a completely automatic working phase necessary to create the slot used to integrate the motherboard to the lower case. Queue-B collects the pallets with the parts before such a phase. The process continues with the third phase involving the manual resource Op2 and the waiting queue Queue-C. The electronic motherboard is placed into the slot and connected. Finally, the upper case closes the controller. The finished parts are removed from the pallets by the SCARA R2 (after waiting in the Queue-D, if necessary) and placed into the output buffer, while the empty pallets return to Queue-A, ready for a new working cycle.

Concerning failures and repairs the SCARAs are subject to failures due to the wrong position of the motherboard on the pallet and the difficulties in removing the lower case from the pallets. In such cases, the resources R1 and R2 requires Op1 and Op2 human resources. They should stop their activities to solve the blocking condition before restart to work.

4.1 Data mining

The process data mining allows to outline the input data in Table 2 about the working times and reliability profiles. Furthermore, the system allows the pallets to wait directly on the conveyor with a FIFO policy. The conveyor and the pallet dimensions, together with the resource positions, allow a maximum queue length of 37, 28, 8 and 8 pallets for the Queue-A, B, C and D, respectively, not to overfill the available space. Finally, the input and output buffers are supposed to be of infinite capacity (no constraints) and the minimum target productivity is of about 240part/h, equal to 15s/part.

Starting from such data and the knowledge of the system behaviour the process is studied through stochastic timed Petri nets, following the introduced approach, to highlight bottlenecks and possible improvement actions.

4.2 Modelling strategy selection

To face the system modelling, the hybrid approach seems to be the best strategy. The resource based strategy is a good choice to model the roller conveyor and the resources, while the process based strategy is of help to model the SCARA failure and repair actions. This is because of the rigid structure of the system, directly coupling atomic components easy to model separately (see Figure 2), and the interactions among human resources and SCARAs during the repair phases.
### Table 2 – Data mining, processing times and reliability profiles

<table>
<thead>
<tr>
<th>Phase</th>
<th>Resource</th>
<th>Processing time</th>
<th>Reliability profile</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time to failure</td>
</tr>
<tr>
<td>1</td>
<td>Op1</td>
<td>Uniformly distributed in [3,7] s/part</td>
<td>No failures</td>
</tr>
<tr>
<td>2</td>
<td>R1</td>
<td>Deterministic, equal to 10 s/part</td>
<td>Uniformly distributed in [1140,2280] s</td>
</tr>
<tr>
<td>3</td>
<td>Op2</td>
<td>Uniformly distributed in [10,17] s/part</td>
<td>No failures</td>
</tr>
<tr>
<td>4</td>
<td>R2</td>
<td>Deterministic, equal to 12 s/part</td>
<td>Uniformly distributed in [1140,2280] s</td>
</tr>
</tbody>
</table>

### 4.3 Subnet study and simulation

Atomic subnets in Figure 2a and 2d are used to model the work phases and the queues (constituting the conveyor). In the former structure, the *End* transition delay is in accordance with the processing time, deterministic or stochastic, while for the latter structure, the overall number of places is equal to the available pallet positions (37, 28, 8 and 8 pallets). Finally, the transition delays among places fit with the conveyor speed and the place capacities are set to one pallet (token), to follow the FIFO strategy. Coupling between subnets is immediate, i.e. the work phase *End* transition feeds the first queue place, while the last queue place feeds the work phase *Start* transition. Figure 5 shows the atomic subnets for the work phases involving Op2 and R2 resources (red and green boxes) and the Queue-A, C and D queues (brown boxes).

**Figure 5** – Work phase and queue atomic subnets (physical strategy)

The atomic subnet modelling the failure and repair strategy is more complex. It is illustrated in Figure 6.

**Figure 6** – Maintenance policy atomic subnet (functional strategy)

The green box models the human work phase, i.e. phases 1 or 3, while the red box models the SCARA automatic phase, i.e. phases 2 or 4. The stochastic timed transition *FailureRY* models the resource *RY* failures (blue box). In the event of a failure a token enters the *Wait OpX to start repair* place looking for the *OpX* to start the repair actions (yellow box). The arches from *Work OpX* and *Idle OpX* places model the human operator arrival and fire the *Repair starts* transition. Repair duration is in accordance with the time to repair stochastic distribution (Table 2) and impacts on the delay of the stochastic timed transition *Repair finished*. The firing of such a latter transition allows the *PhX* and *PhY* to restart. The *Freeze PhX* and *Freeze
PhY places inhibit the work phases to start during failures and repairs. Finally, from Figures 5 and 6, the integration between the work phase and queue subnets and the maintenance policy atomic subnet appears by considering the common places and transitions in the green and red boxes.

The developed stochastic timed Petri net is used to simulate a work shift of 8 hours collecting data about the system performances. The HPSim® integrated development platform is used and run on an Intel Core i7 @ 1.60GHz – 4.00GB RAM laptop. The global simulation time is of 15 seconds per run. A MatLab® customised interface processes the simulation output data.

5. RESULTS AND DISCUSSION

Given the assembly line in Figure 3, a key variable to investigate deals with the effective number of pallets circularly flowing the roller conveyor, hosting the raw parts and the WIP. An insufficient number of pallets generates process delays and productivity losses, while an excess of pallets creates, costs, congestions and the queue saturation. Effective trade-offs are expected, so that multiple simulations, starting from 4 pallets in the system, are done. Results are collected in Figure 7.

Figure 7 – Simulation outcomes: productivity (a), maximum queue length (b) and resource saturation level (c).

The productivity target of 240part/h forces a minimum of 10 pallets in the system (Figure 7a), while the asymptotic behaviour of the productivity curve suggests not to exceed the 12 pallet limit. Concerning the queues, in presence of 11 pallets Queue-C is close to saturation, while 12 pallets lock the system. This is because of the high processing time of Ph3 that is the bottleneck of the system. Figure 7c further highlights such a condition, i.e. the Op2 human resource utilisation is close to 100%, including the time spent to repair the SCARA R2. Given such a configuration, 11 pallets are the unique feasible solution to match the existing constraints to the productivity target.

Consequently, structural improvement actions to the assembly line appear necessary. Two possibilities are of help. The former, called Action 1, deals with the change of the Op2 work position by shifting it closer to R2, so that Queue-C is longer, while the unnecessary Queue-D is reduced. The latter, called Action 2, deals with the duplication of the Op2 human resource and the shift of their positions close to R1 to shorten Queue-C, that becomes not critic in such a configuration, and to increase the Queue-D capacity because of the doubled input rate to such a queue without an increase of the output rate. Both actions are simulated by updating the stochastic timed Petri nets, collecting results for different values of the pallets in the system. The most effective outcomes for Action 1 and Action 2 are in Table 3.

Table 3 – Improvement Action 1 and Action 2, outcomes

<table>
<thead>
<tr>
<th># pallets</th>
<th>Productivity [part/h]</th>
<th>Max length [places]</th>
<th>Op1 saturation level</th>
<th>R1 saturation level</th>
<th>Op2 saturation level</th>
<th>R2 saturation level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action 1</td>
<td>18</td>
<td>253</td>
<td>10 out of 37 places</td>
<td>14 out of 15 places</td>
<td>0 out of 1 place</td>
<td>95.34%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 out of 28 places</td>
<td></td>
<td></td>
<td>39.29%</td>
<td>93.47%</td>
</tr>
<tr>
<td>Action 2</td>
<td>17</td>
<td>280</td>
<td>10 out of 37 places</td>
<td>14 out of 15 places</td>
<td>0 out of 1 place</td>
<td>95.34%</td>
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<tr>
<td></td>
<td></td>
<td>6 out of 28 places</td>
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<td></td>
<td>39.29%</td>
<td>93.47%</td>
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</table>

Both actions increase the as-is system productivity, preventing deadlocks even if the number of pallets in the system is higher. The latter action has the best performances but requires higher investments to duplicate the Op2 human resource, while Action 1 is easier to implement. From a strategic perspective, Action 1 may be a mid-term improvement action, while Action 2 may be a long-term improvement action.
6. CONCLUSIONS

This paper discusses a stepwise approach to support the simulation and assessment of industrial processes through stochastic timed Petri nets, after providing fundamentals about this language and a short review of the state of the art. The adoption of this modelling technique to face operative issues is, actually, limited despite the language potential. An industrial case study, about the simulation and assessment of a circular assembly line is, finally, presented to highlight the benefits coming from the application of the introduced approach to drive the system improvement. Further research deals to refinements in the approach steps easing its applicability, its adoption to other industrial contexts to outline useful rules-of-thumb and best practices for the practitioners and the industrial researchers.

7. REFERENCES

FANTASTIC SPORTS AND THE RESEARCH AND DEVELOPMENT MANAGER OF THE LOGISTIC MODEL BASED ON POSITIONS

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Abstract

The fantastic sports leagues (FSL) are a form of live sports that are surround the sporting world, and increasingly related to different fields of knowledge. To relate the FSL to the logistics, it will be used the Logistical Model Based in Positions (LoMoBaP), who studies the managerial logistics following the functions realized by whom they redeem related positions to the logistics. As the performance of a deprival depends on research has been chosen to the Research and Development Manager. Being the objective of this work: Analyze the fantastic sports leagues through the functions of the Research and Development Manager, of the LoMoBaP.

Keywords: Fantastic sports league, Enterprise logistics, Logistics Models, LoMoBaP (MoLoBaC), Research and Development Manager.

1. INTRODUCTION

The fantastic sports league Emerge as a entertainment among sports journalists and advertisers in the years 60s (Oates, 2009 [1]) and Have had a very noticeable growth, so that for the 2003 it is possible to affirm that more of 15.2 million American adults participated in fantasy sports (Davis and Duncan, 2006 [2]; Duncan, 2007 [3]) and undoubtedly this number has grown, as well Halverson and Smith, 2009 [4], reported that for 2007, the number of members, only in baseball fantasy leagues, exceeds ten million participants. At the beginning of this year 2014, it is possible to affirm that the fantastic sports leagues exist for almost all the sports and there take part of them persons native to almost all the countries of the world. But not only is a different way to see the sports, but in a way or another are related to many fields of human event: education (Close, Dixit and Malhotra, 2005 [5]; Gillentine and J. Schulz, 2001[6]; Halverson and Smith, 2009 [4]), legal (Holleman, 2006 [7]), business (Hill, 2010 [8]), industry (Baerg, 2009 [9]) to mention just a few. Also it is possible to add, as stated Hill (2010 [8]), the fantastic sports are the last acquisition of the sports industry.

It should not escape from this relationship with the fantastic sports leagues the enterprise logistics, to be a field of knowledge that, at the same time, covers many other fields of knowledge. To analyze the relationship of the fantastic sports leagues and logistics will be based on one of four qualitative-quantitative models, created in the academy (García, Hernández and Hernández, 2012 [10]; Hernández, García and Hernández, 2013 [11]). These four models explain the logistics from different perspectives: The model LSPDI (Supply, Production, Distribution and Inverse Logistic (in Spanish el modelo Logístico, Abastecimiento, Producción, Distribución e Inversa [LAPDI])) focuses on the flow; The LoMoBaP (Logistic Model Based on Positions (in Spanish Modelo Logístico Basado en Cargos [MoLoBaC])) studying the logistics through the functions that are carried out by those who are in positions related to logistics; The LoMoBaIPo (Logistic Model Based on Indicators for Positions (in Spanish Modelo Logístico Basado en Indicadores de Cargos [MoLoBaICa])) which analyzes the logistics through performance indicators and STOILMo (Logistic, Strategic, Tactical, Operational with Inverse Logistics Model (in Spanish Modelo Logístico, Estratégico, Táctico, Operativo con logística Inversa [MoLETOI])), studying the logistics based on the administrative pyramid, covering four phases the: Strategic, Strategic-Tactic, Tactic-Operative and Operative. For this work will be used the Logistic Model Based on Positions (MoLoBaC), which consists of forty-four positions (see figure 1), that are
grouped into twelve areas and these in turn into six stages: Supply, Production, Distribution, Inverse, General of the company and General of information. This last stage includes a single area, Information, that is a mixed area, by be conformed by charges of different stages, of the stage Generals of the company includes the position Expansion manager (15) and of his own stage managers of: Virtual Channel (16), News technologies (17), System of Information and Network (18) and Research & Development (19); the numbers beside each position uses the model to identify the same.

As the fantastic sports leagues are based in large part in the management of the information, for this work will be used the last post mentioned, the Research & Development manager. From there, the objective of this work is: Analyze the fantastic sports leagues through the functions of the Research and Development Manager, of the LoMoBaP. From this general objective three specific objectives are derivates:

Present the fantastic sports leagues, commenting on the case of a fantastic soccer league.

Define the position Research & Development manager, emphasizing the functions that it redeems.

To analyze the relationship of the fantastic sports leagues with the logistics, following for it some of the functions of the Research & Development manager.

With regard to limitations and scopes, although it will be used, for the illustration, a fantastic soccer league, There will be no real follow up of the league, but is handled as a hypothetical case, to give more generality to study.

1.1 Methodology

To achieve the general objective and specific objectives derived, it will use 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]), that as described in Hernández, García and Hernández, (2013 [11]), facing investigations without going through the exposition of hypothesis, but a set of steps are followed, which given the flexibility of MIASAD can be adapted to each situation, in particular. For this work will be used: a) to define the problem that, as stated in the objective is analyzing the FSL through the functions of the Research & Development manager, of the MoLoBaC; b) to prepare the first prototype, where it is necessary to identify the users of the final product, that is the main readers of this article, that are all interested in enterprise logistics, from all aspects, especially interested in the functions realized as whom they have positions related to the logistic performance, which there will join the fans of this new way of seeing the sports, that are the FSL. 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 one of them, will be presented the Research & Development manager, in the second chapter, a particular case of FSL will be presented, a soccer league and in the third chapter, that is the main of the work, It will be analyzed through this fantastic soccer league and the functions of the Research & Development manager, The relationship between logistics and the FSL and the work will close with a chapter for conclusions and future investigations; c) obtaining data, in particular on FSL and logistics models, especially the MoLoBaC and specifically the Research & Development manager; d) define alternatives, that is to visualize the different ways to analyze the logistics through of the Research & Development manager; e) evaluate alternatives, see the feasibility of the proposed alternatives according to the objectives established; 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 select alternative could take to the practice and h) establishes controls or mechanisms to recognize that the alternative chosen is still valid in time.

2. THE RESEARCH AND DEVELOPMENT MANAGER OF MOLOBAC

Today, many companies often have in their organizational chart, with a management of research and development (R&D), which is responsible for the entire research process for the development of new products. However, as already it was mentioned, in the MoLoBaC, the Research & Development manager, is located in the area of Information, which is the only area of the stage General of Information, this makes that this manager, Have a field of operation much wider. He becomes responsible for providing information and instruments for handling, for the entire organization up to date with the progress of science and technology. In this way not only contributes in the development of new products, but assists in the management of the information which can lead to new processes and how to meet the challenges. It also provides information to
set new standards for performance and quality, simultaneously helping with the formation of the personal. Also provides information on the best use of machinery and equipment, even to collaborate on the design of new tools, for the organization to carry out their functions in the most effective and efficient manner. However this becomes a major contributor, in saving time, money and to increase the quality and improve customer service.

Before examining the Manager of Research and Development, there are a couple of concepts that are necessary to highlight, the supply chain management and the enterprise logistics and previously the logistics will be defined in a general sense, to facilitate understanding of the relationships of the R&D manager with the FSL.

The logistics is the set of strategies, plans, activities and tasks that must be performed to ensure that a well-defined set and classified of persons, equipments and products or instruments and tools, move in the appropriate ways and means and with appropriate care, to avoid any damage of the same, from sources places, to places destinations, were, through a planned, organized, controlled and coordinated integration, each other and with different elements available in the medium, they can execute tasks assigned a priori, for the benefit of a pre-established objectives.

The enterprise logistics is centered in searching and achieving the best present and future satisfaction of the final costumer and includes the socio-environmental and ethic-legal aspects, the planning, execution and control of all related activities with the procurement, flow, warehousing and maintenance of materials, products and even services; from the raw material source, including costumer through inverse logistics, to the sale point of the finished product whether local or international, massive or enterprise, in the most effective and efficient manner, maximizing performance and the expected quality, while minimizing waste, time and cost using modern information technologies (Hernández, García y Hernández, 2013 [11]).

Supply chain is a wider concept than enterprise logistics 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 y Hernández, 2013 [11]).

2.1 The functions of the Research and Development manager

Based on these concepts and to this broad panorama that handles the Research & Development (R&D) manager, he arise a big quantity of functions that it must redeem to guarantee the good performance of his position. Next, in the table 1, based among others in Basant, 1993 [12]; Evenson and Westphal, 1994 [13]; Wagner, 2008 [14], will present some of the most relevant. In the table 1, refers to the other three models qualitative-quantitative: Supply, Production, Distribution and Inverse Logistic model (LSPDI), Logistic Model Based on Indicators for Positions (LoMoBaIPo) and the Logistic, Strategic, Tactical, Operational with Inverse Logistics Model (STOILMo). Also, in the table 1, beside R&D, in occasions will be used some abbreviations such as HR, human resources, Mgr., manager, IL inverse logistics.

### Table 1 – Some of the most important functions of the Research & Development (R&D) manager.

<table>
<thead>
<tr>
<th>Intrinsically to the position.</th>
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<tbody>
<tr>
<td>01 Define policies in R&amp;D for the entire organization.</td>
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<tr>
<td>02 Create an enabling environment in the entire organization for research and innovation.</td>
</tr>
<tr>
<td>03 Participate in the negotiations, when having to acquire innovations outside the organization.</td>
</tr>
<tr>
<td>04 Activate the mechanisms for the organization through its dependencies becomes a source of new product, equipment and processes development.</td>
</tr>
<tr>
<td>05 Keep the whole organization updated with relevant information to promote the R&amp;D.</td>
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<tr>
<td>06 Promote new ideas that can contribute to the growth of the organization.</td>
</tr>
<tr>
<td>07 Be open to suggestions that can lead to innovation or development of new processes, equipment and products.</td>
</tr>
<tr>
<td>08 Take advantage of every opportunity that presents in the organization, to encourage the proposal for improvements.</td>
</tr>
<tr>
<td>09 Coordinate and promote interdisciplinary team meetings to discuss new ways of achieving the goals.</td>
</tr>
<tr>
<td>10 Generate and propose new fields and sources for research and innovation.</td>
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<tr>
<td>11 Identify and disseminate in the organization, new models for daily tasks and assignments.</td>
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<td>23</td>
</tr>
</tbody>
</table>

**Related to other positions of MoLoBaC**

| 24 | Collaborate, by the Human Resources Manager, for employees to prepare for deepening the R&D. |
| 25 | Seek, next to Layout Mgr that the distributions of the spaces where people perform their daily tasks, facilitate the exchange of ideas, while allowing reflection. |
| 26 | Assist the HR Mgr raise the technical level of the employees, from all areas of the organization. |
| 27 | Encourage, together the General Mgr maintenance and subordinates, innovation in maintaining. |
| 28 | Find the way, along to HR Mgr, doing every job, every day is more challenging. |
| 29 | To ask for help the managers of Cost and Finance, achieve the R&D, without incurring high costs. |
| 30 | Coordinate along the Inventory Mgr and his subordinates, finding new ways to carry inventories. |
| 31 | Take advantage, with the help of the Order processing Mgr., the request of the customers, on all the special, to start new paths for the a R&D. |
| 32 | Working jointly with the Industrial design Mgr. to incorporate and mainly develop new equipment, processes and products. |
| 33 | Initiate studies, together with the Layout and Material handling managers to find ways of distribution of the equipment and machinery in plants, to minimize the movement of products and components. |
| 34 | Maintain, those involved in the picking, updated with new techniques emerging in this area, for it will involve the collaboration of Picking Mgr. |
| 35 | Acting jointly with subordinates managers: Expansion, Virtual Channel, New Technologies and Information Systems and Networks, to include organizing all the new technologies that facilitate the R&D. |
| 36 | Keeping up with the innovations that appear in the warehouse management, and working with the Stores Mgr. |
| 37 | Assist the Dispatch Mgr. to analyze all of the innovations that are presented in this area. |
| 38 | Help the Physical distribution Mgr. and their subordinates to handle the new innovations in the delivery process. |
| 39 | Be attentive to all the improvements that may arise in the management of transport and communicate them to the Transport Mgr. |
| 40 | Find information along with the Packing Mgr. on new types and uses of the packings. |
| 41 | Ask for help to the Marketing and sales Mgr. to learn about new trends of the market. |
| 42 | Participate along with the Projects Mgr. on all those projects that encourage the R&D. |
| 43 | Study together Forecasts Mgr., all trends, products, equipment and processes that may affect the organization. |
| 44 | Acting together to Reverse logistics Mgr. and his subordinates in better use of the products arrive in the IL. |
| 45 | Contributing together to Industrial Safety and internal relationship Mgr., to discover innovations that protect personnel. |
| 46 | Receive advice from Ethical & Juridical Consultant on the legal framework within which will be implemented all the R&D. |
| 47 | Coordinate with Environmental Mgr., that all R & D is respectful of the environment and its regulations. |

**Related to MoLoBaICa, LAPDI, MoLETOI and the enterprise logistics in general**

| 48 | To generate indicators that measure the proper performance and of the whole organization in R&D. |
| 49 | Studying the flows of the organization to take advantage of any opportunity to R&D that they offer. |
| 50 | Improve through the R&D all the operational and tactical performance of the organization. |
| 51 | Ensure that all the logistical aspects of the organization take advantage of the R&D. |
| 52 | Contribute through R&D to meet the vision, mission and guiding principles of the organization. |
| 53 | Incorporate all the innovations themselves or external, which can make the organization more agile than the competition. |

**Related to SCM and the enterprise and its environment as a whole**

| 54 | Establish partnerships with other members of the SCM, to boost R & D among all. |
| 55 | Take advantage of any variation or change in the environment to promote the R&D. |
| 56 | Ensure that the progress in the organization in R&D impact favorably on the whole society. |
| 57 | To improve the R&D in and with the communities of the environment of the organization. |
| 58 | To establish alliances with universities and institutes of investigation, preferably of the environment, to impulse the R&D. |
Knowing the main functions of the Research & Development manager, it will make some comments a fantastic sports league, in particular a soccer league.

3. COMMENTS ABOUT SOCCER FANTASY LEAGUE

As mentioned, there are fantastic sports leagues (FSL) in a lot of sports (Edelman, 2012 [15]; Weaver, 2010 [16]), however, for each sport and each league in particular, has its own rules. Without necessarily including all, will provide some general comments, on a soccer league, in particular make reference to "Desafío la liga" (ESPN, 2012 [17]) and before a few brief comments on this league, presents the following definition of FSL: "Fantasy sports leagues are one way fans can enjoy their favorite sports away from the stadium or arena. A fantasy sports league is made up of a dozen or so participants who compete against each other based on statistics from real-world competitions" (Farquhar and Meeds, 2007 [18], 1208). With regard to the rules of "Desafío la liga", Only submit those that are essential to understand this work and Will be a summary of the submitted in Hernández et al. (2013 [19]) and Hernández, García and Hernández (2014 [20]): The total investment cannot exceed US$ 100 million, Will be used up to 15 players and cannot have more than three players from the same team. With regard to positions will not be more than 2 Goal keepers (GK), 5 defenders (Df), 5 midfielders (Mi) and 3 forwards (Fo). For the formations in the field it is established: Every participant will have to select, of his 15 players, 11 starters for each week of fantasy. Among those 11 players can only have a GK and for the other players some of these formations, ordered: Df-Mi-Fo: 4-4-2 (for default); 4-3-3; 3-4-3; 3-5-2; 5-3-2; 4-5-1 y 5-4-1.

Without entering major details of "Desafío la liga" and with the previous comments on R&D manager, will proceed immediately to review, how the FSL, they can be analyzed, with an approach of the managerial logistics, using for it this manager.

4. FANTASY SPORT LEAGUES AND THE RESEARCH & DEVELOPMENT MANAGER

The sports fantasy leagues (SFL), can be seen as a project of short or medium term, But at the same time it is hoped that they will be analyzed as an activity of the enterprise logistics. Using as starting point the concept of logistics, it should be noted that to achieve a prominent role in a FSL must have strategies, plans and implement a set of activities, in line with the objective. Considering the concept of enterprise logistics, it should be noted, again, the planning and the organization, execution and control that it is necessary to have on every activity realized in pro of gaining the league.

But to satisfy the final client, who in this case is the participant, ethical – legal aspects must be respected, that come expressed in the rules of every league and especially should be kept constant research on the performance of athletes in real life, that have been included in the team of the participant. And it is this first activity, conform the squad, perhaps one of more important that the participant must realize, because on her there will depend in big way the yield that is had (Hernández et al., 2013 [19]; Hernández, García and Hernández, 2014 [20]). And there they begin the relations with the Research and Development manager of the MoLoBaC. The participant must define his own political ones of investigation (01), here and from now on, including the table 2, the number or numbers, now, between parentheses they refer to the function(s) of the R&D manager Identified in table 1. It must create his own mechanisms and propitious ambience for the investigation and innovation (02, 04). At the same time that he must keep up-to-date relevant information (05). Must be open to suggestions and new ideas (06, 07), Take advantage of every opportunity for improvement (08), in this case of his team. It must generate new fields, means and sources of investigation (10), as well as to make use of new models (11). Research should make it a daily act (12), always trying of improving the quality of his search and the results obtained with it (14). He must determine those areas that are more inclined to offer new information (16), in case of a SFL, all the source to let you know about the expected performance of an athlete, especially chosen for his squad. Must use their research to generate new knowledge, That may be useful to follow the strategies established for his team in the league fantastic (19), also must be attentive to new trends that may be giving (21) and finally collect and classify information, while creating mechanisms to take advantage of the best possible (23 y 22).

And they could keep on specifying activities of the participant of a FSL that will relate he to the R&D manager, but for major clarity, are presented in Table 2, where the functions of this manager are associated with the activities of the participant.
Table 2 – Summary of the activities of a participant in a SFL and his relation with the R&D Mgr.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Functions R&amp;D Mgr, that cover</th>
<th>Desired goals</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select your starting squad.</td>
<td>01, 07, 08, 11, 12, 14, 16, 20, 21, 22, 23, 29, 35, 41, 42, 43, 46, 48, 55.</td>
<td>Form a good team starting, that will turn him into contender to win the respective league.</td>
<td>It is perhaps the most important activity, if he has a good team starting can has good results.</td>
</tr>
<tr>
<td>To keep in the team the best sportsmen.</td>
<td>01, 02, 03, 04, 05, 06, 07, 08, 10, 11, 12, 14, 16, 19, 20, 21, 22, 23, 29, 32, 35, 41, 43, 46, 48, 50, 52, 53, 55.</td>
<td>To keep an active team of sportsmen who stand out in his performance.</td>
<td>Some players may lower your performance or injury and better is to replace them.</td>
</tr>
<tr>
<td>Choose the players that will participate in the week.</td>
<td>01, 04, 05, 07, 08, 11, 12, 16, 20, 21, 22, 23, 35, 41, 43, 48, 50, 52, 53, 55.</td>
<td>To have active the sportsmen who could offer the biggest quantity of points.</td>
<td>In case of “Desafío la liga” only 11 players are active every week.</td>
</tr>
<tr>
<td>To take the statistics of the league.</td>
<td>01, 02, 05, 07, 08, 10, 11, 12, 15, 16, 17, 19, 20, 21, 22, 23, 35, 41, 42, 43, 48, 53, 55.</td>
<td>To measure constantly the performance in the league.</td>
<td>In some leagues the competences are direct, in these cases it is very important to know the strategies that there usually uses the rival of the respective week.</td>
</tr>
</tbody>
</table>

As can be seen in Table 2, there are some functions that are repeated in all activities, while there are others that do not appear in any. Of course in any case, it is doing the interpretation of the function of the R&D manager. To adapt it to the activities of a participant in a FSL. It is normal that the functions that do not appear, are related with maintenance, reverse logistics and all those that are related to a point logistics activity. In particular reverse logistics is not detected in a FSL, Since there are no spaces for the possibility that a product in the hands of the consumer and then return to the producer.

Although there do not give details of the direct interpretation that does of the function, for the statement of every function and in accordance with the principal goal that every participant has in a FSL, which is to win the league, you can notice the direct relationship can be established.

With the above comments and with this summary presented in Table 2, it can go to offer some conclusions and future researches.

5. CONCLUSIONS AND FUTURE RESEARCHES

The fantastic sport league (FSL), are not only a new way to watch sports, but have come to many other fields of knowledge. In particular in this work the relationship of these FSL with the logistics was illustrated, to do this is using one of the positions of the Logistic Model Based on Positions (MoLoBaC). The work was supported by the Research & Development manager, because many of its functions, as its name indicates, they have to see with the investigation and this is one of the main concerns that should be a participant in an SFL.

While a SFL is itself a project, was easy to show, through the concept of logistics and in particular the concept of enterprise logistics and especially across the functions of R&D manager that they are closely related to logistics.

Having achieved the objective pursued two lines of research that open, on the one hand continue to work with the SFL and show its relationship to other fields of knowledge and on the other, make use of the logistic models presented here to analyze other fields of knowledge, especially outside business life, That is to say fields that have more to do with aspects of life in society, that of the life in the company.
6. REFERENCES


MEASURING THE EFFICIENCY OF HOSPITALS OPERATING DEPARTMENTS

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²Soroka Hospital, Beer-Sheva, Israel

Abstract

In this study we measured the efficiency of 24 operating departments in Soroka Hospital in Beer-Sheva, Israel. Data Envelopment Analysis (DEA) was used with 5 inputs and 3 outputs over two years. These inputs and outputs reflected logistic parameters and income of the operating rooms. In the three operating sites investigated we found no significant difference in their efficiency. We found that simple room utilization ratio is not sufficient. Benchmark analysis verified inputs and outputs which need improvement in order to reach full efficiency relative to their peers.

Keywords: Efficiency, Data envelopment analysis, Performance measures, Logistics

1. INTRODUCTION

Operating rooms (ORs) are the main cost and profit center in a hospital. They have a special influence on the hospital’s performance as a whole unit [1]. The following main performance measures are often used: OR utilization, waiting time, throughput, leveling, make-span, patient deferrals, financial measures and preferences [1]. Looking at the first measure utilization ratio which defined as the ratio between the number of hours the room was actually used for operation and the number of hours the room was available.

Limitations of the simple utilization ratio are discussed by Basson and Butler [2]. They point out that there is no consideration of various factors affecting the performance such as: repeated operations, time spillover beyond the shift etc. They suggested using Data Envelopment Analysis (DEA). DEA measures relative efficiency with multiple inputs and multiple outputs with variety of units of measurements moreover, improvements are by-product of DEA benchmark analysis [3]. DEA is an ideal tool for assessing accountability in the public sector in general and in hospitals specifically. Hollingswortht [4] cited 165 studies using DEA in hospitals studies.

Basson & Butler [2] studied the efficiency of OR using the following inputs: number of surgeons, no. of anesthesiologists, no. of other workers (nurses, technicians, etc.) and Medical equipment. The outputs they used are: no. of trainees' years provided, no. of students' years given, no. of surgeries performed, no. of surgery hours performed, no. of publications.

The main purpose of our study is to measure the efficiency of OR in Soroka hospital in Israel. There are three operating sites we investigated in our study to see if there is significant difference among the operating sites over the two years. We also compared the DEA relative efficiency rankings to the rankings of simple room utilization ratio. Benchmark analysis verified the parameters (inputs and outputs) needed for improvement in order to reach full efficiency relative to their peers.

2. OPERATING ROOM UTILIZATION RATIO

The utilization ratio of an operating department relates to the utilization of the operating room by the department. Let us define:

\[ H \] – operating room time allocated to the department
\[ t_i \] – actual time of operation i
\[ n \] – number of the operations of the department
Soroka hospital utilization in 2009 was 78.83%. In the literature 97% is the desired utilization [5]. Limitations of the simple utilization ratio are given by Basson & Butler [2]. There is no consideration of various factors such as: teaching which takes place in OR, repeated operations, and time spillover beyond the shift.

3. DEA FORMULATION

The basic version of DEA model – CCR was developed by Charnes Cooper and Rhodes [3]. It assumes constant returns to scale. It measures the total efficiency of n Decision Making Units (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), we solve n problems, one for each DMU. The problem of DMU k finds, v_{ik}, the optimal weight of input i, and u_{rk}, the optimal weight of output r of DMU k, which maximize its relative efficiency measure, h_{kk}.

The basic ratio used here is:

$$ h_{kj} = \frac{\sum_{r=1}^{s} u_{rk} y_{rj}}{\sum_{i=1}^{m} v_{ik} x_{ij}} $$

The problem of DMU k is:

$$ \text{max} \ h_{kk} $$

Subject to:

$$ h_{kj} \leq 1, \quad j = 1...n $$

$$ u_{rk}, v_{ik} \geq \varepsilon $$

$$ i = 1...m $$

$$ r = 1...s $$

The relative efficiency is the ratio between the sum of weighted outputs and weighted inputs. If with its ideal weights DMU k does not receive the maximal efficiency score 1 (100%), then DMU k is not efficient; i.e., other DMUs (or a combination of DMUs) received the maximal score 1 in the ideal weights of DMU k. However, if DMU k receives the maximal efficiency rate 1 then unit k is relatively efficient. Thus, the efficient frontier is the collection of the efficient DMUs (which receive efficiency value 1).

The problem can be formulated as a Linear Programming (LP). DEA provides the efficient frontier. Obviously, the input and output weights vary greatly from one DMU to another.

3.1 Benchmark analysis and identifying improvements

The Dual problem of the LP problem is crucial for a benchmark analysis, and for identifying improvements needed in each input/output [3]. The slack variables of the dual problem represent the improvements needed in each input/output. The non-zero dual variables, of problem k determine the peers of the k-th DMU which caused it to be inefficient. Thus, benchmark analysis is performed by listing these peers and investigating them. A linear combination of these peers caused DMU k to be inefficient.

3.2 BCC version: variable return to scale

While the above CCR version of DEA represents constant returns to scale, Banker Charnes and Cooper [6] introduced the BCC version of DEA, which allows variable returns to scale, by adding a constant variable to the output of the objective function and constraints, -k_{ik}, of problem k.
Since CCR is the special case where $\omega_k=0$, obviously, always the BCC efficiency score will be equal or more than the CCR score. Consequently, the number of efficient units in BCC will be equal or more than the number in the CCR version (under the same conditions).

### 3.3 Ranking in the DEA context via CE

We used the Cross Efficiency (CE) index to rank-scale the police stations (see review of the literature on ranking in DEA context, [7]). CE measures the efficiency of each DMU by using the weights of all other DMUs as well, creating a cross efficiency matrix, from which an average measure is calculated for $k^{th}$ DMU as follows: $\bar{h}_k = \frac{1}{n} \sum_{j=1}^{n} h_{jk} / n$. Each DMU, $k$, receives $n$ efficiency scores, $h_{jk}$, from using the optimal inputs' and outputs' weights of DMU $j$, for $j=1,\ldots,n$. The final score is the average score. The weights of the CCR model are used as the base for CE ranking, rather than the BCC model, since the constant $\omega$ in the BCC model may be negative for some DMUs, and may affect the evaluation of other DMUs negatively in the cross evaluation. All $h_{jk}$ are measured via the weights of all the DMUs, which assures that each weight must be positive for some DMUs, thus there is no need to restrict the weights in the CCR version used for CE ranking. Thus, we can rank the DMUs, by simply ordering them and ranking them according to the CE score.

Advantages of CE: first, it provides common weights to all the DMUs, while DEA’s weights vary greatly from one DMU to another. Second, CE has values which are continuously distributed, while DEA has many values equal to 100%. Thus with CE we can use statistical inference. The CE tends to Normal distribution as the number of DMUs increases. Usually there no ties, thus full ranking is simple.

### 4. OUR CASE STUDY: SOROKA HOSPITAL

The main purpose of this study was to rank-scale the surgical departments based on several criteria: some we wish to minimize (inputs), and some we wish to maximize (outputs). The data included 24 operating departments in the hospital operating in 3 sites of surgery rooms: Northern, Southern, and Women. We took annual data of 2008 and 2009, during the morning shift – the main shift. The data was collected from the information systems of the surgery rooms and the operating departments.

The variables included 5 parameters to minimize which are analogous to inputs:

1. The average time span between surgeries (avg. 12.28min.)
2. No. of surgery hours allocated to Dept. (Avg. 1023h.)
3. No of spillovers beyond the shift (3:PM, Avg. 38.2)
4. No. of repeated surgeries (44.45)
5. Avg. starting hour of operating (Avg. 8.29Am.).

Three parameters we wish to maximize (analogous to outputs):

1. Income – Health Ministry tariff (Avg. 8,350NIS)
2. Actual Avg. hour of end of day (Avg. 1.85Pm.)
3. Actual no. of surgery hours (Avg. 765h.)

Overall the objectives of the study were:

a. To differentiate between efficient and inefficient departments
b. Full rank-scaling of operating departments' efficiencies
c. To verify significant differences between the years 2008-2009
d. To indicate improvements needed in the departments
e. To verify significant differences among the 3 operating sites
f. To verify differences between DEA efficiency and the utilization factor

### 5. THE RESULTS

We run two DEA versions: CCR and BCC each for each of the two years – 2008 and 2009. We also run the BCC for the two years combined; namely, the data of the two years was considered as one set of 48 DMUs,
then the average score of the two years was calculated for each department. We used Banxia Frontier software to run all DEA scores [8].

We calculated the correlations between various DEA efficiencies and found that they are statistically significant, as shown in Table 1. This was done for validation of the results, showing their consistency.

### Table 1 – The correlations among the various DEA scores

<table>
<thead>
<tr>
<th>Version</th>
<th>CCR 08_09</th>
<th>CCR 2009</th>
<th>CCR 2008</th>
<th>BCC 08_09</th>
<th>BCC 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCC 2008</td>
<td>0.56**</td>
<td>0.35</td>
<td>0.438**</td>
<td>0.9**</td>
<td>0.727**</td>
</tr>
<tr>
<td>BCC 2009</td>
<td>0.703**</td>
<td>0.571**</td>
<td>0.503*</td>
<td>0.871**</td>
<td>1</td>
</tr>
<tr>
<td>BCC 08_09</td>
<td>0.704**</td>
<td>0.479*</td>
<td>0.518**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>CCR 2008</td>
<td>0.509*</td>
<td>0.525**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCR 2009</td>
<td>0.794**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.1 The CE Rank-scaling

As we indicated in section 3 DEA provides dichotomy of the DMUs into two groups: efficient or inefficient. The weights of the inputs and outputs vary greatly from one DMU to another. Now we utilize CE in order to fully rank scale all the operating departments utilizing all the weights of the inputs and outputs of all the DMUs. The rank scaling was done for each of the two years, and the combined data of the two years.

Using correlations we found that there were significant correlations between CE and DEA results, which verified the results (see Table 2). Moreover, there were significant correlations between the scores of the two years for both scores: CCR scores of 2008 and 2009 had .525 correlation, and CE scores of 2008 and 2009 had 0.736 correlation.

### Table 2 – The correlations between CE and CCR.

<table>
<thead>
<tr>
<th>Version</th>
<th>CE_CCR 08_09</th>
<th>CE_CCR 09</th>
<th>CCR_CE 08</th>
<th>CCR 0809</th>
<th>CCR 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCR 2008</td>
<td>0.34</td>
<td>0.449*</td>
<td>0.362</td>
<td>0.509*</td>
<td>0.525**</td>
</tr>
<tr>
<td>CCR 2009</td>
<td>0.354</td>
<td>0.557**</td>
<td>0.182</td>
<td>0.794**</td>
<td></td>
</tr>
<tr>
<td>CCR 0809</td>
<td>0.65**</td>
<td>0.691**</td>
<td>0.437*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCR_CE 08</td>
<td>0.61**</td>
<td>0.736**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE_CCR 09</td>
<td>0.711**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.2 Improvements needed – Benchmark analysis

Based on the CCR results of 2009 we found that overall reductions are needed in the following parameters:

1. 35.4% in Avg. time span between surgeries
2. 10.5% in No. of surgery hours allocated to the departments
3. 11.7% in No. of spillovers beyond the shift
4. 6.17% in No. of repeated surgeries
5. 3.29% in Avg. starting hour of operating

Overall increases needed in the following parameters:

1. 31.38% in Income
2. 0% in Actual Avg. hour of end of day
3. 1.59% in Actual no. of surgery hours.

These improvements indicated above are averages over all 24 operating rooms. There is great variability among the improvements needed in the various operating rooms, ranging from 0% in the efficient operating rooms to tens of percent in some inefficient operating rooms. There are two parameters that need major improvement of 31-36%, and another two parameters that need average improvement of 10-11%. All other parameters needed less than 6.2%.
In summary: The major causes for inefficiency of operating rooms in Soroka hospital is caused by two parameters: one is logistic: "the time span between surgeries" (which requires the largest reduction of about 35%), and the second is "the income" (which requires the largest increase of about 31%).

As shown in Table 3, efficient department 21 appears most often as peer of 10 other inefficient departments, while efficient department 2 appears almost as often as peer of 9 other inefficient departments.

<table>
<thead>
<tr>
<th>Efficient peers</th>
<th>Inefficient department</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,21</td>
<td>12</td>
</tr>
<tr>
<td>2,21</td>
<td>13</td>
</tr>
<tr>
<td>2,21</td>
<td>16</td>
</tr>
<tr>
<td>2,11,20</td>
<td>22</td>
</tr>
<tr>
<td>11,21</td>
<td>17</td>
</tr>
<tr>
<td>2,21</td>
<td>9</td>
</tr>
<tr>
<td>15,21</td>
<td>18</td>
</tr>
<tr>
<td>2,21</td>
<td>23</td>
</tr>
<tr>
<td>2,20,21</td>
<td>14</td>
</tr>
<tr>
<td>1,2,6,21</td>
<td>3</td>
</tr>
<tr>
<td>2,21</td>
<td>8</td>
</tr>
</tbody>
</table>

5.3 Comparison among the sites
As shown in the one way Analysis Of Variance (ANOVA) we performed here, there was no significant difference among the efficiencies (CE) of the 3 operating sites. The average efficiency of the Southern site was 72.19, of the Northern site 64.76, and the Women site 73.1. To be able to use ANOVA we verified that our CE scores are Normally distributed, via Kolmogorov-Smirnov test and Shapiro-Wilk.

5.4 Comparison between the efficiency and the utilization:
Table 6 provides the ranking via DEA and the ranking via room utilization ratio. We found significant difference between the average utilization and average efficiency (also in the ranks). We used Mann Whitney test.
6. SUMMARY AND CONCLUSIONS

We studied here the efficiency of 24 operating rooms at Soroka hospital, in Beer-Sheva, Israel. These operating rooms are located in 3 sites within the hospital: South, North, and Women. The data was collected for two consecutive years 2008 and 2009. Five inputs (parameters to minimize), and 3 outputs (parameters to maximize) were utilized to measure the operating rooms efficiency. We used Data Envelopment Analysis (DEA) to measure the relative efficiency, utilizing several versions of DEA. Moreover the Cross Efficiency (CE) measure was used.

Here are our major findings: There was no significant difference among the three sites efficiency. The various DEA versions and CE scale-ranking were significantly correlated. There was no difference between the efficiency of the two years considered (2008 and 2009). There was significant difference between the simple room utilization ratio and the CE efficiency.

The benchmark analysis reveals that three main inputs required high decrease to improve the efficiency: the time span between surgeries (35%), no. of surgery hours allocated (10%), and no. of spillovers beyond the shift (11%). Only one main output required high increase to improve the efficiency: the income (31%).

Although there was no significant difference between the OR utilization (the simple ratio) and DEA ranking both indicate that there is a problem in the ORs logistics: the three parameters which need most of the cuts to improve relate to the room utilization. However DEA points at the detailed parameters, moreover, DEA pointed at the low income as another major source of inefficiency of operating rooms in Soroka hospital.

For future research, more data is needed, for example to include number of nonappearance of patients to surgery, as Basson et al. [2] point it out as a major cause for OR inefficiency.

All figures and tables should be saved with the document, positioned in their places and named accordingly to its position in the text.

7. REFERENCES


KNOWLEDGE MANAGEMENT THROUGH THE MATERIAL HANDLING MANAGER

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Abstract

Given the interrelationship of the enterprise logistics with the entire organization, a line of investigation has been generated to study the generation and management knowledge through the positions of the Logistic Model Based in Position (LoMoBaP), which examines the enterprise logistics following the functions performed by each of its forty-four positions. Choosing the Material Handling Manager, the objective of this work arises: Analyze the process of generation and management knowledge of an organization through the functions of the Material Handling manager of LoMoBaP.

Keywords: Enterprise logistics, Knowledge Management, Logistic Models, LoMoBaP (MoLoBaC), Material Handling manager (MHM).

1. INTRODUCTION

The generation and knowledge management is a permanent restlessness for businesses (O’Leary, 1998 [1]; Nissen et al., 2000 [2]; Rus et al., 2001 [3]), hence organizations are constantly trying to improve the management. One approach to analyzing the generation and knowledge management is the business logistics, from which have already produced several works (Barreto, 2012 [4]; Hernández et al. 2012 [5]) this made it possible, in some way create a line of research. This line of research is based on one of the four models qualitative-quantitative created in the academy to study the business logistics (García et al., 2012 [6]; Hernández et al., 2013 [7]). Each of these four models explained the logistics from different points of view: The Supply, Production, Distribution and Inverse Logistic model (LSPDI, in Spanish el modelo Logístico, Abastecimiento, Producción, Distribución e Inversa [LAPDI]), analyzes the enterprise logistics through its flows; The Logistic Model Based on Positions (LoMoBaP, in Spanish Modelo Logístico Basado en Cargos [MoLoBaC]) it centre on the functions that realize those who redeem positions related to the logistics; The Logistic Model Based on Indicators for Positions (LoMoBaIPo, in Spanish Modelo Logístico Basado en Indicadores de Cargos [MoLoBaICa]), makes use of the structure of MoLoBaC and analyzes the logistics across indicators of performance and the Logistic, Strategic, Tactical, Operational with Inverse Logistics Model (STOILMo, in Spanish Modelo Logístico, Estratégico, Táctico, Operativo con logística Inversa [MoLETOI]), studies the logistics centering on the Strategic, Tactical and Operative of the administrative pyramid. On this work the interest will be centre in the LoMoBaP, in which forty-four positions are present, grouped in twelve areas and these in turn in six stages: Supply, Production, Distribution, Inverse, General of the company and General of information. In the stage of production, they are, four areas, the first one of them, Order Processing, it is a mixed area since it is formed by two positions of his own stage, Distribution: Picking manager (22) and Order Processing manager (25) and three positions of the production stage: Stores manager (21), Industrial design manager (23) and Material Handling manager (24); the numbers beside each position uses the model to identify the same.

In this research, to analyze the generation and knowledge management, there will use the last mentioned position the Material Handling manager (MHM). From there, the objective of this work is: Analyze the process of generation and management knowledge of an organization through the functions of the MHM of LoMoBaP. To achieve this general objective will include three specific objectives:

Define an approach for the generation and knowledge management.

Define the position Material Handling manager, emphasizing the functions redeems.
To analyze how across the functions of the MHM, it is generated and it is possible to manage the knowledge for an organization.

With regard to limitations and scopes, will not be through the case of a particular company, But that will be handled a hypothetical case of a general nature, to give greater universality to the study.

1.1 Methodology

This general objective and specific objectives derived, is achieved by making use 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 was developed to create decision support systems (DSS), but because of its flexibility it adapts to different types of investigations. IAMDSS, as described in Hernández et al., (2013 [7]), conducts investigations without going through the exposition 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 is indicated in the objectives is analyze the generation and knowledge management through functions MHM of MoLoBaC; b) to prepare a first prototype, where is identify the users of the final product, in this case, because it is a scientific article, will identify its main readers, that are all interested in the generation and management of knowledge in organizations, to which are added the students of enterprise logistics, from all aspects, especially those who are interested in the functions performed for those who have related positions to the logistics performance. Also, there was established the structure of the article, which in addition to the introduction will consist of three central chapters, in the first one of them, presents the model generation and knowledge management to be used, in the second chapter, the MHM and their functions are presented and in the third chapter, which is the main work, analyzed as through functions MHM, it is possible to create and to manage knowledge in an organization. The work will close with a chapter for conclusions and future investigations; c) obtaining data, particularly on generation and knowledge management and logistic models, including specifically MoLoBaC and their MHM; d) establishing alternatives, that is to display the different ways to analyze the generation and knowledge management through the MHM; e) evaluate alternatives, see the feasibility of the proposed alternatives according to the objectives established; f) selecting the 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.

2. BRIEF COMMENTS ON THE GENERATION AND KNOWLEDGE MANAGEMENT

As already indicated, the topic generation and knowledge management is critical in organizations, there have been created approaches and models for study. Signalize Otim (2006 [8]), taking into consideration expressed by several authors, when we speak of knowledge there is a series of relevant processes: creation, transfer, generation, implementation, coding, retention and sharing knowledge. In this paper the focus will be on the generation and knowledge management and will follow the same approach from previous works (Barreto, 2012 [4]; Hernández et al. 2012 [5]), to maintain continuity in the line of research established. Before presenting the model used, mainly following Hernández et al. (2012 [5]), will be presented a few brief comments on knowledge management, with an emphasis on the dynamic knowledge. Knowledge in organizations is widely documented and serves the managerial purposes, however it is expansive and complex and is a challenge for researchers (Zachry et al., 2007 [9]). It is also important to note that knowledge is the core of creating and sustaining competitive advantage, but external knowledge sources are often not readily available, making it necessary to create knowledge internally, addition it should be noted, that as important as the source of knowledge, external or internal, is the ability to absorb this knowledge (Volberda et al., 2009 [10]). It may be noted that organizations working to preserve, protect and recreate knowledge they possess (Carney 2006 [11]) by which knowledge management is a key aspect of large institutions. And the creation of organizational knowledge is the process of making available and amplifying knowledge created by individuals, as well as to crystallize it and to connect it to the system of knowledge of the organization (Nonaka & von Krogh, 2009 [12]). Also it is recognized that the knowledge is an intangible resource, although recognize Wang et al. (2009 [13]) that intangible resources may produce more competitive advantages that the tangible. In concordance with the processes previously identified by Otim (2006 [8]), Warkentin et al. (2001 [14]), make reference to: create, preserve, use and share knowledge and then describe four functions or processes of the knowledge management: externalization, internalization,
intermediation and cognition. And this is as important to direct attention to the construction of knowledge through the iteration of tacit knowledge and explicit, which points out Carney (2006 [11]), knowledge management that tries to understand and use the dynamics of both knowledge, tacit and the explicit, to lead to higher levels of competitiveness in the extremely changing environments. It can accept the explicit knowledge as that which is presented and captured in graphic and written (Nonaka and von Krogh, 2009 [12]), while tacit knowledge is in the brains of people without them knowing, that is to say the persons do not know what they know (Wan et al., 2010 [15]). With these comments, especially on the tacit and explicit knowledge and the internalization and externalization and thinking in the dynamic knowledge, it is possible to introduce the knowledge management model that will be used in this work. There will be reference to the work of Nonaka et al. (2000 [16]), who focus the process of creation and knowledge management in a dynamic spiral, which covers three main dimensions: SECI, Ba and Knowledge assets. SECI, are the initials for Socialization, Externalization, Combination and Internalization and correspond to the four modes of conversion of the knowledge that presents Nonaka et al. (2000 [16]), the Ba is related to the context necessary to create the knowledge, which must be specific, in the sense of who is involved and how participating in the creation of knowledge, the Ba unifies the physical space, the virtual one and the shared space, since it could be the last one, the ideas shared by an organization, from there that the key to understanding the Ba is interaction and his condition to be open and changing Nonaka et al. (2000 [16]).

With respects to the Knowledge assets, Nonaka et al. (2000 [16]), the refer to the specific assets of the organization, that are indispensable for the knowledge management. To understand how the knowledge assets is created, acquired and exploited, proposed categorize them in four types: Experimental, Conceptual Systemic and Routine Knowledge assets Nonaka et al. (2000 [16]).

Without more details of the management of SECI, the Ba and the Knowledge assets, will close this brief presentation of the knowledge management, giving a general definition of what it could be the dynamic knowledge: "An intangible resource, it is the core of creativity and constitutes a creation, diffusion, transference, internalization and absorption of knowledge process by itself, parting from the transformation and conversion of tacit knowledge into explicit knowledge and continuously through a spiral from the latter, generate tacit knowledge to reinitiate a permanent cycle. From this, Dynamic Knowledge is expansive and complex and one of the most important sources of competitive advantages for the enterprises" (Hernández et al. 2012, 552 [5]).

3. THE MATERIAL HANDLING MANAGER OF MoLoBaC

The Material Handling manager of MoLoBaC is responsible for all the movements, of all the assets, that the organization has for sale, to which it must add equipment and materials of use, that for some reason need to be displaced from one place to another. For this reason, he must be responsible for the movement of raw materials, packing and any other input that comes to the organization, from the point of reception, up to the respective stores and equal it is under his responsibility the by-products and products in preparation, from warehouses to processing centers and vice versa when necessary and of course the movement of finished and end products ready for commercialization, from warehouses to points of entry and even mounting on the vehicle that will take them to their final destination, that is to say the consumers or the commercialization channels. Similarly he correspond the responsibility of the movement of all products arriving for reverse logistics, until incorporated fully or in parts or pieces to the various points of production or release. In addition to these assets, the MHM is responsible for moving byproducts and wastes to their place of use or disposal as appropriate. To ensure that all these movements are made in the best way, trying to create value rather than a financial charge, the MHM, is also responsible for the equipment and materials necessary to achieve these displacements. The large set of responsibilities makes this manager, Must comply with a large amount of functions in order to achieve the proposed objectives.

It is interesting to stand out, that although the parameters that apply to the construction industry in some cases move away much from the manufacturing industry, in which this work focuses, relating to material handling are some elements taken from Proverbs et al. (1999 [17]) which are common to both, such as: efficient operation of equipment, safety, costs, skills in managing technology and experience of personnel, planning, control and minimization of time.

Before examining the Materials Handling manager, there are a couple of concepts, although they appear in other papers in this Proceeding or can be reviewed in (Hernández et al., 2013 [7]), are necessary to highlight, the supply chain management and the enterprise logistics.
3.1 The functions of the Material Handling manager

The need to bring all supplies to the place where they are needed, obliges the Material Handling manager to meet very effectively and efficiently with their functions, while maintaining a high interaction with all areas of the organization. Of these multiple functions and interactions that it must redeem, the MHM, in the table 1, based on or inspired among others in Andersson and Bengtsson (2013[18]), Ericsson and Heldmann (2013 [19]), Finnsgard et al. (2011 [20]), Hanson (2012 [21]), Proverbs et al. (1999 [17]), it present some of the most relevant. In the table 1, in general one will speak about materials, to having referred to products and other inputs and sometimes some such abbreviations will be used as Mgr. for manager, HR for human resources, R&D for Research & Development, IL for inverse logistics, IS&IR, for Industrial Safety and Internal Relations and MH and MHM, for handling of materials or material handling and Material Handling manager, since already it had been used.

<table>
<thead>
<tr>
<th>Table 1 – Some of the most important functions of the Material Handling manager</th>
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</thead>
<tbody>
<tr>
<td><strong>Intrinsic to the position.</strong></td>
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<td>30</td>
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<tr>
<td><strong>Related to other positions of MoLoBaC</strong></td>
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<td>31</td>
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<tr>
<td>32</td>
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<td>33</td>
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</tbody>
</table>
Table 1 – Some of the most important functions of the Material Handling manager (continuation)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>34</td>
<td>Assist Layout Mgr., in the distribution of the machinery and equipment, to facilitate the MH.</td>
</tr>
<tr>
<td>35</td>
<td>Establish routes of travel for equipments that move materials, supported by the Layout Mgr.</td>
</tr>
<tr>
<td>36</td>
<td>Support the IS&amp;IR Mgr., for that the workstations respond to ergonomic designs.</td>
</tr>
<tr>
<td>37</td>
<td>Support the IS&amp;IR Mgr, in policies of cleanliness, order and hygiene in the workplace.</td>
</tr>
<tr>
<td>38</td>
<td>Try to ensure, together with managers IS&amp;IR and industrial design, that in their workstations the displacements of the employees are within their comfort zone.</td>
</tr>
<tr>
<td>39</td>
<td>Participate with the Store and Picking managers to establish a distribution of materials that facilitate their subsequent management.</td>
</tr>
<tr>
<td>40</td>
<td>To know thoroughly all the materials used in the organization, to be able to give suggestions to the Procure manager and his subordinates of materials of substitution.</td>
</tr>
<tr>
<td>41</td>
<td>To guarantee the quality of the processes of MH, for it will receive the support of the Quality Mgr.</td>
</tr>
<tr>
<td>42</td>
<td>Coordinate together the Maintenance general Mgr. and his subordinates, the maintenance of equipment for MH.</td>
</tr>
<tr>
<td>43</td>
<td>Assist in the management of spare and parts, to facilitate maintenance.</td>
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<tr>
<td>44</td>
<td>Participate, through its staff in the work of corrective maintenance, especially plant shutdowns. To support the managers of preventive maintenance and major maintenance.</td>
</tr>
<tr>
<td>45</td>
<td>To work actively with the managers of Cost and Finance, to minimize costs in the MH.</td>
</tr>
<tr>
<td>46</td>
<td>To receive support of the R&amp;D Mgr. and his subordinates, to know any new information on MH.</td>
</tr>
<tr>
<td>47</td>
<td>Meet the inventory of MH equipment through the Equipment and Parts manager.</td>
</tr>
<tr>
<td>48</td>
<td>Be informed via the Inventory manager and his subordinates, of all materials of the organization.</td>
</tr>
<tr>
<td>49</td>
<td>Know, through the Processing orders Mgr. the pending orders.</td>
</tr>
<tr>
<td>50</td>
<td>Coordinate with the Physical distribution Mgr. and their subordinates the movement orders to be dispatched.</td>
</tr>
<tr>
<td>51</td>
<td>To act in joint form with the managers of Transport and his subordinates and of Physical distribution and his subordinates, so that the transport and the delivery of the orders are realized without flaws in the MH.</td>
</tr>
<tr>
<td>52</td>
<td>To ask the Ethical &amp; Juridical Consultant for consultancy, when there should move materials that need special regulations.</td>
</tr>
<tr>
<td>53</td>
<td>To give collaboration to the Environmental Mgr., so that the MH does not cause environmental impacts.</td>
</tr>
<tr>
<td>54</td>
<td>Study together the Forecast Mgr., all trends, products, equipment and processes that may affect the MH in the organization.</td>
</tr>
<tr>
<td>55</td>
<td>Participate with the Project Mgr. on projects that help improve MH.</td>
</tr>
<tr>
<td>56</td>
<td>To coordinate together the Reverse logistics Mgr. and his subordinates, the movement of all materials those come to the organization through reverse logistics.</td>
</tr>
<tr>
<td>57</td>
<td>Collaborate with the Customer Service Mgr. and his subordinates, for MH work to maintain high standards of customer service.</td>
</tr>
<tr>
<td>58</td>
<td>Related to MoLoBaICa, LAPDI, MoLETOI and the enterprise logistics in general.</td>
</tr>
<tr>
<td>59</td>
<td>Working for assembly lines and workstations are designed considering the MH.</td>
</tr>
<tr>
<td>60</td>
<td>Generate indicators to measure their own performance and their subordinates.</td>
</tr>
<tr>
<td>61</td>
<td>Being who promote, to establish material flows, both direct and inverse, more suitable.</td>
</tr>
<tr>
<td>62</td>
<td>Studying the flows of the organization to take advantage of any opportunity for improvement in MH.</td>
</tr>
<tr>
<td>63</td>
<td>To improve through the MH, the tactical performance and especially the operational one of the organization.</td>
</tr>
<tr>
<td>64</td>
<td>Ensure all logistical aspects of the organization receive a positive impact of the MH.</td>
</tr>
<tr>
<td>65</td>
<td>Contribute to fulfill the vision, mission and governing principles of the organization, through the MH.</td>
</tr>
<tr>
<td>66</td>
<td>Minimize waste of materials and time, through good management of materials.</td>
</tr>
<tr>
<td>67</td>
<td>Related to SCM and the enterprise and its environment as a whole.</td>
</tr>
<tr>
<td>68</td>
<td>Make efforts to ensure that MH equipment are friendly neighboring communities.</td>
</tr>
<tr>
<td>69</td>
<td>Share with other members of the supply chain advances in MH.</td>
</tr>
<tr>
<td>70</td>
<td>Disseminate progress in MH, which may have positive impact in society.</td>
</tr>
</tbody>
</table>
Intentionally in this paper has tried not to make other consideration of the use of robotics in material handling (Chen et al., 2006 [22]; Tsourveloudis et al., 2000 [23]), especially when weak or limp materials are used, since the approach was intended to focus more on people than in the same materials. After having presented the main functions of the MHM, will be passed to check as through them it can generate and management knowledge in organizations.

4. KNOWLEDGE MANAGEMENT AND MATERIAL HANDLING

Of the functions of the Materials Handling manager (MHM) it is possible to see that it has the need to contact practically all the areas of the organization, this makes it a focal point for the generation and knowledge management. Just as with the Industrial Design manager (García et al., 2012 [24]), from the moment they are conceived ideas and it has a partial knowledge of the materials to use, begin the contacts with the MHM, to have his opinion if they can or not to handle the involved materials. Thus the MHM it has a big opportunity to be a generator and agent of the knowledge.

For his constant interaction and exchange with all the areas of the organization it achieves the Socialization, simultaneously that takes part in the conversion of the tacit knowledge in explicit, facilitating thus the Externalization. Additionally, the MHM It is a vehicle that acts to convert this explicit knowledge in an explicit knowledge more complex, making it part of the combination and finally, on having been connect different areas of the organization, it helps in the process of integrating this explicit knowledge to the tacit knowledge, thus achieving the Internalization, completing the SECI. He contributes also with the Ba, since the displacement of materials at different time intervals allows him to define an area spatiotemporal, where the exchange of knowledge generation and management is carried out. The MHM participates in the production process since they are just ideas without concretor. This early and constant intervention, they allow him also to take part in the creation of the knowledge, from his beginnings, for which it is a direct drive of the transformation, of the tacit knowledge in explicit and again in tacit, to complete the cycle established by Nonaka et al. (2000 [16]).

The MHM Helps to remake the tacit knowledge shared, including, for their constant interaction, emotional and affective aspects, what would be recorded in the Experimental Knowledge assets of all staff of the organization. Also helps formalize this explicit knowledge on specific objects, particularly finished products and to explain the achievements to the rest of the organization, also becomes a generator of Conceptual Knowledge assets. Their interaction with almost everyone in the organization and having to establish rules for the use and management conditions of the materials and knowledge, also allows him to participate in the organization, systematization and even legalization of knowledge and therefore also involved in the formation of Systemic Knowledge assets. Finally the MHM through its large interactions, it must be explaining how each of the individuals can contribute in new achievements and to disseminate this practical knowledge formed in the organization, therefore it is part of Routine Knowledge assets. What there does to him protagonist of all the basic aspects of handling of the knowledge presented in the model of Nonaka et al. (2000 [16]), as it was established in Hernández et al. (2012 [5]).

In summary to illustrate the influence of the MHM in the creation and management of the knowledge, while continuing as presented by Barreto (2012 [4]; Hernández et al., 2012 [5]), it will be mainly used the scheme proposed in García et al. (2012 [24]), through tables, as has been derived in subsequent work. For this case in Tables 2 through 10 the impact occur MHM in each of the components of the model of Nonaka et al. (2000 [16]). The first tables, the 2, 3, 4 and 5 dedicated to the SECI, the 6 to the Ba and last four 7, 8, 9 and 10 to knowledge assets.

<table>
<thead>
<tr>
<th>Socialization</th>
<th>SECI (Socialization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share experiences with subordinates (almost all functions 1 to 30) and with practically all the positions of the MoLoBaC (functions 31 to 58), including external entities (functions 67 to 69).</td>
<td></td>
</tr>
<tr>
<td>Exchange of information (practically all his functions).</td>
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</tr>
<tr>
<td>Frequent meetings (although have not been identified in the functions).</td>
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</tbody>
</table>
Table 3 – The Materials Handling manager and the Externalization.

<table>
<thead>
<tr>
<th>SECI (Externalization)</th>
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<tbody>
<tr>
<td>Externalization</td>
<td>Crystallized knowledge, through its intrinsic functions and with practically all the positions of the MoLoBaC (functions 1 to 58).</td>
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<tr>
<td></td>
<td>Transforms tacit knowledge into explicit (principally functions: 01, 02, 04 to 08, 10 to 27, 29, 30, 32 to 40, 42 to 44, 47 to 49, 51 to 54 and 57 to 67).</td>
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<tr>
<td></td>
<td>Articulated work.</td>
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<td></td>
<td>To forms the basis of new knowledge.</td>
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<td></td>
<td>These last two aspects through all its functions.</td>
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</table>

Table 4 – The Materials Handling manager and the Combination.

<table>
<thead>
<tr>
<th>SECI (Combination)</th>
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<tbody>
<tr>
<td>Combination</td>
<td>Systematized knowledge through his subordinates and practically all the positions of the MoLoBaC (functions 1 to 58).</td>
</tr>
<tr>
<td></td>
<td>Convert explicit knowledge into more explicit knowledge.</td>
</tr>
<tr>
<td></td>
<td>Help to process, combine, edit and convert knowledge into new knowledge.</td>
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<tr>
<td></td>
<td>These last two aspects through all its functions.</td>
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Table 5 – The Materials Handling manager and the Internalization.

<table>
<thead>
<tr>
<th>SECI (Internalization)</th>
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<tbody>
<tr>
<td>Internalization</td>
<td>Integrates knowledge through his subordinates and almost all positions MoLoBaC (functions 1 to 58).</td>
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<tr>
<td></td>
<td>Converts explicit knowledge into tacit knowledge. This is achieved through constant interaction with all members of the organization, bringing the knowledge of each other.</td>
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<tr>
<td></td>
<td>Spread the new knowledge to take advantage of the lessons learned.</td>
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Table 6 – The Materials Handling manager and the Ba.

<table>
<thead>
<tr>
<th>Ba</th>
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<tbody>
<tr>
<td>Ba</td>
<td>To move the materials from one place to another, is a constant supporter of the Ba to provide practically to all positions of the MoLoBaC: Space. Time. Conditions. Space-time.</td>
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<td></td>
<td>This is reflected mainly in the functions: 01 to 06, 08 to 30, 32 a 44, 47, 49 to 52, 54, 57 to 64 y 66.</td>
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Table 7 – The Materials Handling manager and the Knowledge assets Experimental.

<table>
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<tr>
<th>Experimental Knowledge assets</th>
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<tbody>
<tr>
<td>Experimental</td>
<td>Practically all the positions of the MoLoBaC.</td>
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<td></td>
<td>Includes emotional and affective aspects, mainly with his subordinates and all members of the organization.</td>
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<td></td>
<td>Tacit knowledge sharing and reinstitute.</td>
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<tr>
<td></td>
<td>In any case remains specific to each organization.</td>
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<tr>
<td></td>
<td>Participating practically all the functions.</td>
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</table>
Table 8 – The Materials Handling manager and the Knowledge assets Conceptual.

<table>
<thead>
<tr>
<th>Conceptual Knowledge assets</th>
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<tbody>
<tr>
<td>Practically all the positions of the MoLoBaC.</td>
</tr>
<tr>
<td>Images and symbols: Plans, checklists, description of materials.</td>
</tr>
<tr>
<td>Explicit knowledge.</td>
</tr>
<tr>
<td>Shared knowledge.</td>
</tr>
<tr>
<td>Principally the functions 1 to 32.</td>
</tr>
</tbody>
</table>

Table 9 – The Materials Handling manager and the Knowledge assets Systemic.

<table>
<thead>
<tr>
<th>Systemic Knowledge assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practically all the positions of the MoLoBaC.</td>
</tr>
<tr>
<td>Explicit knowledge organized, systematized and legalized (Ethical &amp; Juridical consultant).</td>
</tr>
<tr>
<td>Easy to understand and to transmit.</td>
</tr>
<tr>
<td>More visible of the Knowledge assets.</td>
</tr>
<tr>
<td>All the functions.</td>
</tr>
</tbody>
</table>

Table 10 – The Materials Handling manager and the Knowledge assets Routine.

<table>
<thead>
<tr>
<th>Routine Knowledge assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practically all the positions of the MoLoBaC.</td>
</tr>
<tr>
<td>Tacit knowledge is implanted and embedded in the daily work of the organization.</td>
</tr>
<tr>
<td>Organizational culture.</td>
</tr>
<tr>
<td>It is essentially practical.</td>
</tr>
<tr>
<td>All functions, mainly 30 to 66.</td>
</tr>
</tbody>
</table>

With the illustrated although the tables 2 to 10, it is possible to see clearly the influence of the MHM in the creation and management of the knowledge and it can be passed to present some conclusions and proposed future lines of investigation.

5. CONCLUSIONS AND FUTURE RESEARCHS

The generation and management of knowledge, Remains a vital aspect to the companies and all organizations in general. So try to study the knowledge management through the enterprise logistics is to have an additional search window, with the advantage that logistics is involved in many areas of organizations, allowing it to be an entity that not only generates knowledge, but also the dynamics.

In this, as in similar works, followed, the Material Handling manager, one of the positions of the Logistic Model Based on Positions (LoMoBaP) and could find over sixty functions related with this manager, which allows him to maintain a high interaction with almost every member of the organization. Through the functions MHM and following a model of knowledge management based on knowledge spiral, could present a series of relations having the MHM with dynamic knowledge, acting as a generator and knowledge manager.

While maintaining this line of research should seek to work with other positions of the MoLoBaC and analyze for each one of them, since they can act as generating and managing entities of the knowledge, through the functions to be perform.

6. REFERENCES


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INDICATORS AND THE PICKING MANAGER OF THE LOGISTIC MODEL BASED ON POSITIONS

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Abstract
To facilitate the study of the enterprise logistics four qualitative – quantitative models have been created, two of them are the Logistic Model Based in Position (LoMoBaP), that studies the logistics through functions and the Logistics Model Based on Indicators for Positions (LoMoBalPo), that explaining the logistics through management indicators. To study the LoMoBalPo, should be done on a position of the LoMoBaP. In this paper the Picking Manager (PM) is used, from there the objective: Explain how LoMoBalPo works, through the Picking Manager of the LoMoBaP.

Keywords: Enterprise logistics, Logistic Models, LoMoBaP (MoLoBaC), LoMoBalPo (MoLoBalCa), Picking Manager.

1. INTRODUCTION
Enterprise logistics is related to almost all areas of an organization, between can highlight: Human resources, either through the supply chain management (Shub and Stonebraker, 2009 [1]), or even through the Enterprise resource planning (ERP) (Madapusi and D'Souza, 2012 [2]), Production (Gimenez and Ventura, 2005 [3]; Karageorgos et al., 2003 [4]), Quality (Brah and Lim, 2006 [5]; Morash et al., 1996 [6]), Marketing (Emerson and Grimm, 1996 [7]; Gimenez, 2006 [8]), Finance (Ballou et al., 2000 [9]; Koch, 2001 [10]; Hofmann, 2009 [11]). This great interrelationship is a great advantage when it want to have a general knowledge of the organizations, But it is a disadvantage when it want to explain the logistics to those who are just beginning to their study. This wide dispersion of knowledge that has forced in the academy will create four models qualitative-quantitative to facilitate their study (García et al., 2012 [12]; Guerrero, 2013 [13]; Hernández et al., 2013 [14]). These model explained the logistics from different points of view: the Supply, Production, Distribution and Inverse Logistic model (LSPDI) focuses on the logistical flows to analyze the business logistics; the Logistic Model Based on Positions (LoMoBaP, in Spanish Modelo Logistico Basado en Cargos [MoLoBaC]) takes into consideration all the functions performed in positions related to enterprise logistics; The Logistic Model Based on Indicators for Positions (LoMoBalPo, in Spanish Modelo Logistico Basado en Indicadores de Cargos [MoLoBalCa]), overlaps the MoLoBaC and analyzes the logistics through performance indicators and the Logistic, Strategic, Tactical, Operational with Inverse Logistics Model (STOILMo), it is based on three components of the administrative pyramid, the: Strategic, Tactical and Operative and including the inverse logistics, it analyzes the managerial logistics.

On this work the interest will be centre in the MoLoBalCa, but, as already it was said, for its study it needs the structure of the MoLoBaC, specifically there will be done use of one of its 44 positions, the Picking Manager (PM), which belongs to the distribution stage, specifically the area of Order Processing, that is one of the mixed areas of the model, Since it is composed by the positions: Picking Manager (22) and Order Processing Manager (25) that belong to a stage of distribution and Stores Manager (21), Industrial design Manager (23) and Materials Handling Manager (24) pertaining to the area of production and it is necessary to clarify that the numbers that have been placed next to every position, the model used for identification of the same.
Than indicated in the preceding paragraph, the objective of this work arises: Explain how MoLoBaICa works, through the Picking Manager of the MoLoBaC. To achieve this general objective will include three specific objectives: a) To present the Logistic Model Based on Indicators for Positions (MoLoBaICa); b) To define the position Picking Manager (PM), emphasizing the functions that it redeems and c) To show how the MoLoBaICa works through the functions of the PM.

With regard to limitations and scopes, although it will be based in case of a company in particular, this one will not be mentioned for reasons of confidentiality and the study will be submitted as a hypothetical case of a general nature, to give greater universality work.

1.1 Methodology

To achieve this general objective and specific objectives, it will use the Integrated-Adaptable Methodology for the development of Decision Support System (IAMDSS), which was developed to create decision support systems (DSS), but because of its flexibility it adapts to different types of investigations (Barreto, 2012 [15]; Guerrero, 2013 [13]). IAMDSS, as discussed in Hernández, et al., (2013 [14]), undertake the research without passing through the development of scenarios, but a set of steps are followed, which can be adapted to each situation, in particular. For this work will be used: a) to define the problem that, as is indicated in the objectives is to explain how the MoLoBaICa works, through the PM of the MoLoBaC; b) to prepare the first prototype, where, between other aspects, there identify the users of the final product, in this case, because it is a scientific paper, will identify its main readers, that are all interested in the measurement of management in organizations, to which are added the students of logistics, from all aspects, especially interested in the functions realized as whom they have related charges to the logistic performance. Also, there was established the structure of the article, which in addition to the introduction will consist of three central chapters, in the first one of them, will be presented on the MoLoBaICa, in the second chapter, PM and its functions will be presented and in the third chapter, that is the main one of the work, be presented as MoLoBaICa can make use through the functions PM. Work will close with a chapter for conclusions and future research; c) search data, particularly on measuring of the managerial management through indicators and on logistic models, in particular the MoLoBaICa and MoLoBaC and specifically the PM; d) establishing alternatives, that consists of visualizing how there can measure the managerial management through indicators making use of the functions of the PM; e) evaluate alternatives, see the feasibility of the proposed alternatives according to the objectives established; f) select the best alternative, in accordance with the secondary, tacit or explicit objectives that have been contemplated; g) to implement the select 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.

2. THE LOGISTIC MODEL BASED ON INDICATORS FOR POSITIONS (LoMoBaIPo)

The measurement of the managerial management has been a constant preoccupation and the logistics cannot escape of it, so it is common to find management indicators in the same (Martínez and Pérez, 2001 [16]; Sabóia et al., 2006 [17]). In particular these authors work with Balance Scorecard, technique which is often in the literature, however, since it was through it can usually achieve very general indicators, it has been preferred use MoLoBaICa. The advantage of MoLoBaICa is that there can be generated indicators that allow to do measurements at all the levels, be already for the functions, the positions, the person, the areas, the stages and the company as a whole (Guerrero, 2013 [13]; Hernández and García, 2010 [18], Hernández et al., 2012 [14]; [19]). MoLoBaICa, from the academic point of view, as indicated Hernández et al., 2012 [19], can be viewed in three stages: definition of the indicators; measurement of the indicators and submission of the report of results. Nevertheless when MoLoBaICa is applied to an organization a major number of stages appear: define persons to be studied; interview each of the selected, which also allows to associate to a position of MoLoBaC; Define the functions and the weight that will take each one in the study, at the same time that determines the number of indicators that will be used to analyze each function; set each one of the indicators that will be used and the weight to each indicator will be in the valuation of the function; evaluate each individual through the indicators established; evaluate for each individual their different functions and At the same time the evaluation of each one of these people; if there is evaluated a group of individuals who belong to different positions, to evaluate positions, to evaluate areas, to evaluate stages and evaluate the company as a whole if possible. Details of each of these stages can be seen in the above mentioned works, especially in Hernández et al., 2012 [19].
From the above, it is noteworthy that developing an indicator means that it has been given a name, a brief description of the same, it has established the mathematical expression that represents it, which obviously must be a quotient, have been established low, medium and high values that can take the indicator, also the measurement period is set and its conditions of review, and the value of this indicator for the function being evaluated. As for the evaluation of every individual it is possible to measure his performance in direct form, by observation or it is established in accordance with the statistics that are had of his performance. Major details of all these aspects will be seen in the chapter 5, when there does the evaluation of the PM, which will be presented below.

3. THE PICKING MANAGER OF MoLoBaC

The Picking Manager (PM), in the Logistic Model Based on Positions (MoLoBaC), is responsible for preparing the orders that will be dispatched to end customers. Implying that is responsible for the entire process by which they are prepared, and gather together a range of products to meet a specific request (Guerrero, 2013 [13]). And it should be noted that orders picking has been identified as the most intensive labor activity and more expensive for almost all stores (Koster et al., 2006 [20]). To comply with this process should take the different products or groups of products that are at the end of the production line or generally in the finished goods warehouse, forming with them a group that should be packaged, to reach the end customer in the best possible conditions. These orders, before being dispatched to end customers, are conveniently grouped to minimize time losses. This performance has a very intrinsic relationship with two other MoLoBaC managers, the Stores Manager and Packing Manager. Hence sometimes, some of its functions to be confused with the functions of these two managers mentioned. Even as the prepare orders usually involves material handling, also there are functions shared with the Materials Handling Manager. But under none circumstances it is possible to think that the functions of the PM are subordinated and much less simple and elementary. Conversely, it is necessary that the PM meet a lot of functions of varied complexities, for the company to achieve its main objective is no other than to satisfy the end customer.

And this objective, to satisfy the end customer requires, before beginning to analyze the functions of the PM, will discuss a couple of concepts, although they appear in other papers in this Proceeding or can be reviewed in (Hernández et al., 2013 [14]), are necessary to highlight, the supply chain management and the enterprise logistics.

3.1 The functions of the Picking Manager

This need to maintain satisfied end customers, it force the PM to meet very effectively and efficiently with all its functions, At the same time, as already indicated, which maintains a high interaction with many of the positions and areas of the organization. Of this group of functions to be performed, the PM in Table 1, based among others on Brynzér et al., (1994 [21]); Koster et al., (2006 [20]); Petersen et al., (2004 [22]); Poon et al., (2009 [23]) but mainly in Guerrero (2013 [13]) are some of the principals. In the table 1, abbreviations will be used such as Mgr. for Manager, WMS for Warehouse Management System, OL by order line, which is the number of different items or items that comprise an order, MH for Material Handling, HR by Human Resources, R&D for Research and Development, IL for reverse logistics, IS&IR, by Industrial safety and internal relations, PM for Picking Manager, since already it had been used. Some of these abbreviations also used in the subsequent tables.

<table>
<thead>
<tr>
<th>Table 1 – Some of the most important functions of the Picking Manager.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>01</strong></td>
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<td><strong>02</strong></td>
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<td><strong>03</strong></td>
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<td><strong>04</strong></td>
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<td><strong>07</strong></td>
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<td><strong>09</strong></td>
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<td>31</td>
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<tr>
<td>32</td>
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<tr>
<td>33</td>
</tr>
<tr>
<td>34</td>
</tr>
<tr>
<td>35</td>
</tr>
</tbody>
</table>

Related to other positions of MoLoBAC:

| 36 | Discuss with the warehouse and layout managers the internal distribution of warehouses to facilitate picking. |
| 37 | Coordinate with the Warehouse Manager, before starting the picking, the availability of the necessary products. |
| 38 | Track the flow of products through WMS and support Storage Manager. |
| 39 | Contact the Procurement Manager and his subordinates to ensure the products for picking. |
| 40 | Assist the Inventories Manager establish inventory levels, to facilitate picking. |
| 41 | Request support for Storage Manager for through the WMS to generate every day OL to execute. |
| 42 | To establish together with the Manager of Stores, the zones for every type of product, in order to facilitate the picking. |
| 43 | To ask the Stores Manager to keep it informed about the levels of stock and the place of the products. |
| 44 | To coordinate with the MH Mgr., all the displacements of products and materials during the picking. |
| 45 | Ensure, together the Packaging Manager for appropriate conditions of packaging to ensure product integrity until arrival at destination. |
| 46 | Knowing through the Ethical & Juridical Consultant regulations on products to fulfill all. |
| 47 | Validate that the OL for WMS generated represent customer orders, especially in the quantities demanded. |
| 48 | Define together the Order Processing Manager, the policies serving orders. |
| 49 | Participate with the Project Manager on projects that help improve the work of picking. |
| 50 | To know the specific conditions to the moment of the delivery of the products: batch, expiration dates, products in quarantine, emergencies, among others. This with help of Warehouse and Inventory managers. |
| 51 | Establish mechanisms to agilely handle rush orders, pending or detained by the customer, not delivered and other special cases. |
Table 1 – Some of the most important functions of the Picking Manager (continuation).

| 52 | Sort orders prepared in the area of packing according to the route of delivery and special requirements for each client. In accordance with managers Storage, Packing and Dispatch. |
| 53 | To verify, together with the managers of Quality and Packing, the conditioning and packing of the ready orders. |
| 54 | To respect and to offer the suitable conditions of handling according to the specified for the Quality manager. |
| 55 | Know about the new requirements of the clients. With the support of the managers of Customer service and Marketing. |
| 56 | Assist the IL Mgr. to define the final destination and location in the warehouses of the returned products. |
| 57 | Be aware of new technologies that facilitate the picking. Supported by the R&D Mgr. and his subordinates. |
| 58 | Collaborate with IS&IR Mgr, for the work of picking respond to ergonomic postures. |
| 59 | Support the IS&IR Mgr, in policies of cleanliness, order and hygiene in areas where the picking is done. |
| 60 | Know thoroughly all the products handled in the organization, to give suggestions to the Manager of Procurement and subordinates of input replacement. |
| 61 | Coordinate together the Maintenance General Mgr. and his subordinates, maintaining equipment for the picking. |
| 62 | Working in coordination with the Cost and Finance managers to minimize costs in the picking. |
| 63 | Know the inventory of equipment for the realization of picking through the Spare & Equipment Mgr. |
| 64 | Knowing through the Order Processing Manager, pending orders. |
| 65 | Coordinate with the Manager of Physical Distribution and subordinates the priority orders to be dispatched. |
| 66 | Acting jointly with Transportation and Physical Distribution managers and their subordinates for the picking facilitate dispatch, transport and delivery of orders. |
| 67 | Ask for advice from the Ethical & Juridical Consultant, to make picking of products requiring special regulations. |
| 68 | To collaborate with the Environmental Mgr. for the picking does not cause negative environmental impacts. |
| 69 | Study together the Forecasts Mgr., all trends, products and orders that may affect the picking. |
| 70 | Collaborate with the Customer Service Mgr. and his subordinates for the picking helps to maintain high standards of customer service. |

Related to MoLoBalCa, LAPDI, MoLETOI and the enterprise logistics in general.

| 71 | Work to ensure that the flow of products during the picking is as efficient as possible. |
| 72 | Generate indicators to measure their own performance and subordinates. |
| 73 | To help establish the product flows, both direct and inverse, more suitable. |
| 74 | To improve through the picking the whole tactical performance and especially the operational one of the organization. |
| 75 | Contribute to fulfill the vision, mission and guiding principles of the organization, through the picking. |
| 76 | Minimize waste products and especially of time, through good management of the picking. |
| 77 | To guarantee a better service to the final client through the picking. |

Related to SCM and the enterprise and its environment as a whole.

| 78 | Be alert to changes in the economy which may affect demand for certain products and therefore their picking. |
| 79 | Perform picking so as to favor the other members of the SCM. |
| 80 | Share with other members of the supply chain developments in the management of picking. |
| 81 | Ensure that the picking, especially through the packaging, have a positive impact in society. |

Although there are still functions mentioned by Guerrero (2013 [13]), not included here, by the large amount of functions presented you can see the versatility and importance of Manager Picking. From these functions, although Hernández et al., (2012 [19]) recommend the use of approximately twelve, for reasons, principally of space, only three of them will take to illustrate as it is possible to use the MoLoBalCa to measure the performance of the PM.

4. THE PICKING MANAGER AND MoLoBalCa

The three selected functions to illustrate the MoLoBalCa, of which part the construction of the tables 2, 3, 4a, 4b, 4c, 5a, 5b, 5c and 6, are more randomly chosen for their importance and are: 03.- Determining the type or types of picking to use in the organization, 13.- Maintain strict control of the time spent on the work of picking and 31.- Adapt the process of picking the size and structure of the warehouse.
Principally for reasons of space, the initial tables used by MoLoBaICa will be omitted, it is recommended to check Hernández et al., (2012 [19]; 2013 [14]) for major details. Continuation, in the table 2, presents the hours dedicated to each of the selected functions and in the table 3 there appears the weight that each of these functions have for the study, as well as the number of indicators used to measure them. On the other hand in the stage 4 (4a, 4b and 4c) provides details of each of these indicators.

**Table 2 – Hours dedicated to the functions of the Picking Manager.**

<table>
<thead>
<tr>
<th>Employee: H. G.</th>
<th>Interviews first date: 27/ 02 2014</th>
<th>Interviews final date: 28/ 02 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position in the enterprise: Picking responsible.</td>
<td>Total hours for period of time (Ht): 40</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>Dedicated hours (Hd)</td>
<td>(Hd / Ht) * 100</td>
</tr>
<tr>
<td>03.- Determining the type or ...</td>
<td>06</td>
<td>06 / 40 = 15,00 %</td>
</tr>
<tr>
<td>13.- Maintain strict control of ...</td>
<td>32</td>
<td>32 / 40 = 80,00 %</td>
</tr>
<tr>
<td>31.- Adapt the process of ...</td>
<td>08</td>
<td>08 / 40 = 20,00 %</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>115 %</td>
</tr>
<tr>
<td>Total Hd / Ht: Minor to 1 _ Equal to 1 __ Major to 1 <em>X</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments: Slightly overloaded employee. All its functions are related to Picking.

MoLoBaC Position: Picking Manager.

To determine the indicators of the function 13, there have taken as activities of major consumption of time the route, the selection, the consolidation and packing, therefore created an indicator for each. And although the comparison is time for OL, to express the indicator is compared with the average time of an average OL. So the mathematical expression is identical for all four indicators, but refers to different times. And in fact each of these indicators can say is double.

**Table 3 – Weight and number of indicators for the functions of the Picking Manager.**

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Function weight</td>
</tr>
<tr>
<td>03.- Determining the type or ...</td>
<td>30%</td>
</tr>
<tr>
<td>13.- Maintain strict control of ...</td>
<td>45%</td>
</tr>
<tr>
<td>31.- Adapt the process of ...</td>
<td>25%</td>
</tr>
</tbody>
</table>

**Table 4a – Indicators of the function 03.**

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Function: 03.- Determining the type or types of picking to use in the organization.</td>
<td></td>
</tr>
<tr>
<td>Function weight in evaluating the position (1 a 100): 30</td>
<td></td>
</tr>
<tr>
<td>Indicator Name</td>
<td>Indicator Description</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Revision of the type of picking</td>
<td>Reviews by Customers</td>
</tr>
</tbody>
</table>

The indicator Revision of the type of picking is measured every six months and it is expressed in number of reviews by customers average.

| Types of picking | Quantity of types of picking | (Types of picking) / (OL) | 0,20 | 0,25 | 0,50 | Two straight times out of range | 80 |

The indicator Quantity of types of picking is measured annual and expressed as the number of types by OL.
In function 13, the type of picking is analyzed and times measured, to establish new averages, of being necessary, when any modification is realized in the stores, which could affect the works of picking. A measurement must be complete, that is to say, should review all times all affected indicators.

In the tables 5 (5a, 5b and 5c), the measurement is taken of each indicator for the employee in study, and as in the tables 4, a table is dedicated to each of the three functions studied.

### Table 4b – Indicators of the function 13.

<table>
<thead>
<tr>
<th>Indicator Name</th>
<th>Indicator Description</th>
<th>Mathematical Expression (Quotient)</th>
<th>Values</th>
<th>Revision conditions:</th>
<th>Indicator value for the function (1 to 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route</td>
<td>Route time (Minutes) / (Average time)</td>
<td></td>
<td>1,05 0,95 0,90</td>
<td>Three straight times out of range</td>
<td>100</td>
</tr>
<tr>
<td>Selection</td>
<td>Time in picking the products (Minutes) / (Average time)</td>
<td></td>
<td>1,05 0,97 0,95</td>
<td>Three straight times out of range</td>
<td>95</td>
</tr>
<tr>
<td>Consolidation</td>
<td>Time to consolidate (Minutes) / (Average time)</td>
<td></td>
<td>1,05 0,95 0,93</td>
<td>Three straight times out of range</td>
<td>90</td>
</tr>
<tr>
<td>Pack</td>
<td>Time to pack (Minutes) / (Average time)</td>
<td></td>
<td>1,03 0,99 0,97</td>
<td>Two straight times out of range</td>
<td>85</td>
</tr>
</tbody>
</table>

The indicator Route measured daily and expressed for each OL and as the average day.
The indicator Selection measured daily and expressed for each OL and as the average day.
The indicator Consolidation measured daily and expressed for each OL and as the average day.
The indicator Pack measured daily and expressed for each OL and as the average day.

### Table 4c – Indicators of the function 31.

<table>
<thead>
<tr>
<th>Indicator Name</th>
<th>Indicator Description</th>
<th>Mathematical Expression (Quotient)</th>
<th>Values</th>
<th>Revision conditions:</th>
<th>Indicator value for the function (1 to 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>Reviews for changes (Reviews) / (Changes)</td>
<td></td>
<td>1,00 1,00 1,25</td>
<td>Five straight times out of range</td>
<td>95</td>
</tr>
<tr>
<td>Measurements</td>
<td>Time measurements (Measurements) / (Changes)</td>
<td></td>
<td>1,00 1,25 1,50</td>
<td>Two straight times out of range</td>
<td>100</td>
</tr>
</tbody>
</table>

The indicator Analysis is measured annually and expressed as the number of revisions by changes in the stores.
The indicator Measurements is measured annually and expressed as the number of comprehensive measurements by changes in the stores.
Table 5a – Measurements of the indicators of the function 03.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Numerator value</th>
<th>Denominator value</th>
<th>Indicator value</th>
<th>Value (1 to 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revision of the type of picking</td>
<td>116</td>
<td>48</td>
<td>2,4167</td>
<td>96,67 (2,5 = 100)</td>
</tr>
<tr>
<td>Types of picking</td>
<td>64</td>
<td>162</td>
<td>0,3951</td>
<td>98,78 (0,40 = 100)</td>
</tr>
</tbody>
</table>

Finally in Table 6 all previous values are consolidated and each of the functions are valued and from them the position is evaluated, the areas, the stages and the company as everything. Of having other positions they could be evaluated, adding lines to this table 6.

Table 5b – Measurements of the indicators of the function 13.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Numerator value</th>
<th>Denominator value</th>
<th>Indicator value</th>
<th>Value (1 to 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route</td>
<td>39</td>
<td>38</td>
<td>1,0357</td>
<td>92,86 (1,00 = 100)</td>
</tr>
<tr>
<td>Selection</td>
<td>25</td>
<td>24</td>
<td>1,0417</td>
<td>91,66 (1,00 = 100)</td>
</tr>
<tr>
<td>Consolidation</td>
<td>7</td>
<td>8</td>
<td>0,8750</td>
<td>100,00 (1,00 = 100)</td>
</tr>
<tr>
<td>Pack</td>
<td>6</td>
<td>6</td>
<td>1,0000</td>
<td>100,00 (1,00 = 100)</td>
</tr>
</tbody>
</table>

Table 5c – Measurements of the indicators of the function 31.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Numerator value</th>
<th>Denominator value</th>
<th>Indicator value</th>
<th>Value (1 to 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>16</td>
<td>15</td>
<td>1,0667</td>
<td>100,00 (1,00 = 100)</td>
</tr>
<tr>
<td>Measurements</td>
<td>14</td>
<td>15</td>
<td>0,9333</td>
<td>93,33 (1,00 = 100)</td>
</tr>
</tbody>
</table>

Table 6 – Evaluation of the functions, position, area, stage and company.

<table>
<thead>
<tr>
<th>Function: Determining ...</th>
<th>Function Weight (Pf): 30</th>
<th>Hours dedicated to the function (Hd): 06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator</td>
<td>Obtained value in the indicator (Vi)</td>
<td>Indicator weight (Pi)</td>
</tr>
<tr>
<td>Revision of ...</td>
<td>96,67</td>
<td>100</td>
</tr>
<tr>
<td>Types of ...</td>
<td>98,78</td>
<td>80</td>
</tr>
<tr>
<td>Sum</td>
<td>195,45</td>
<td>180</td>
</tr>
</tbody>
</table>
Table 6 – Evaluation of the functions, position, area, stage and company (continuation).

<table>
<thead>
<tr>
<th>Function Value (Vf)</th>
<th>Function Weight (Pf): 45</th>
<th>Hours dedicated to the function (Hd): 32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function: 13 Maintain ...</td>
<td>Indicator Obtained value in the indicator (Vi)</td>
<td>Indicator weight (Pi)</td>
</tr>
<tr>
<td>Route 92,86 100</td>
<td>9286,00</td>
<td></td>
</tr>
<tr>
<td>Selection 91,66 95</td>
<td>8707,70</td>
<td></td>
</tr>
<tr>
<td>Consolidation 100,00 90</td>
<td>9000,00</td>
<td></td>
</tr>
<tr>
<td>Pack 100,00 85</td>
<td>8500,00</td>
<td></td>
</tr>
<tr>
<td>Sum 384,52 370</td>
<td>35493,70</td>
<td></td>
</tr>
</tbody>
</table>

Function Value (Vf) \( \frac{\text{Sum Vi} \times \text{Pi}}{\text{Sum Pi}} \times \text{Pf} \times \text{Hd} \)
\( \frac{35493,70}{370} \times 45 \times 32 = 138137,64 \) (95,93%)
Accumulated Pf * Hd = 1620

Function: 31 Adapt the ... | Function Weight (Pf): 25 | Hours dedicated to the function (Hd): 08 |
| Indicator Obtained value in the indicator (Vi) | Indicator weight (Pi) | Vi * Pi |
| Analysis 100,00 95 | 9500,00 |
| Measurements 93,33 100 | 9333,00 |
| Sum 193,33 195 | 18833,00 |

Function Value (Vf) \( \frac{\text{Sum Vi} \times \text{Pi}}{\text{Sum Pi}} \times \text{Pf} \times \text{Hd} \)
\( \frac{18833,00}{195} \times 25 \times 08 = 19315,90 \) (96,58%)
Accumulated Pf * Hd = 1820

Position Value (Vc) \( \frac{\text{Sum Vf} \times \text{Sum Pf} \times \text{Hd}}{175022,94 \times 1820} = 96,17 \% \)
(All the functions of the position)

Area Value (Va) \( \frac{\text{Sum Vf} \times \text{Sum Pf} \times \text{Hd}}{175022,94 \times 1820} = 96,17 \% \)
(All the functions of the positions of the area)

In the table 6 appear all the final values of the study, that in this case refer to only one manager and to only one persona, but can be as complete as the company wishes. With these results, it can proceed to present some conclusions and review future lines of investigation.

5. CONCLUSIONS AND FUTURE RESEARCHS

Table 6 is the result of having presented the Logistic Model Based on Positions (LoMoBaP [MoLoBaC]) and have taken one of his forty-four positions, Picking Manager, to analyze it through his functions, of which few ones were selected, To illustrate how it works the Logistic Model Based on Indicators for Positions (LoMoBaIPo [MoLoBaICa]) thus achieving the objectives of this research.

It can be concluded that MoLoBaICa, seems to be of great help to measure the performance of an organization, since there allows to measure punctual indicators, the position, the person, the area, the stage and the company as whole.

Of here two lines of investigation arise, one more academic that it is to apply MoLoBaICa to different positions of the MoLoBaC, what has been already doing. Another line of investigation is more directed to the companies, to which it is recommended to apply MoLoBaICa, to isolated positions or areas of the company or even the company as a whole and repeat these studies, every certain period of time, such as a semester or a year, this way to take a record of how it improves the performance of the organization, or of the analyzed positions.

6. REFERENCES


STORAGE SYSTEM WITH MOVABLE RACKS – A CASE STUDY

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Abstract
Nowadays many storage systems exist, requiring proper analysis for a decision which one to implement in a real case. This professional paper presents cost-based analysis of one case study, aimed to evaluate implementation of storage system with moveable pallet racks. Main advantage of moveable racks, storage space saving, justified higher investment costs. Second part of paper illustrates implementation process of selected variant in practice.

Keywords: movable rack, pallet rack, green and brown field

1. INTRODUCTION
According to Gudehus and Kotzab [1], storage systems and their operation are highly underestimated areas of logistics. Due to lack of knowledge, many warehouses are wrongly planned or not optimally operated, which causes under occupation or shortages of storage locations and underutilization or bottlenecks of storage devices. The combinatorial possibilities for the layout and arrangement of warehouses lead to the different storage types, which in combination with storage units, storage devices and in- and outward transport system determine storage technique.

There are several basic types of storage systems in use in practice, related to the different possible arrangements of the storage locations and operational properties. One of them is movable rack storage system as an alternative to the most often used storage system of selective pallet racks. Taking into consideration that shortage of space is a universal problem, and that proper utilization of the available space is the best way to combat storage problems and space shortages, it is important to properly evaluate movable rack system (and capability of space saving) in comparison with other storage type systems.

This paper is a professional paper that shows a case study of construction a green field facility of a warehouse (together with several facilities of a production plant). Case study is based on cost-based analysis of four alternatives. Two types of racks (selective pallet rack and movable pallet rack) and two types of forklifts (reach truck and VNA turret truck) were used in combinations for analysed alternatives.

For the purpose of better understanding of paper, brief description of storage systems (racks) and forklifts, as well as some notes on planning industrial facilities, relevant to this case study, are given in next section. Cost-based analysis of a case study and some insights into implementation of selected solution (installation) are presented in Section 3. Final remarks are given in conclusion.

2. RACKS, FORKLIFTS AND FACILITY PLANNING OF A CASE STUDY

2.1 Selective and movable pallet racks
Selective (or standard, single-deep) pallet racks are most often used storage system for palletized goods in warehouses. Simple, inexpensive and adjustable solution, it offers direct accessibility to all pallet units (locations), decent utilization of storage space using vertical dimensions (several levels with up to more than 10 meters high). However, selective pallet racks requires aisles between each 2 parallel rows of racks,
leading to the not so good space (surface) utilization. Some reduction of aisle space requirements is possible using very narrow aisle (VNA) forklifts.

Moveable (or mobile, sliding) racks, on the other hand, can obtain approximately two times more storing efficiency than fixed racks, because each rack moves independently and creates a workable aisle. It is most suited for storage of pallet and case units. Due to the fact that the rack is on a cart, it is especially earthquake–proof and utilizes drop prevention features effectively keep stock from falling. Additionally, the aisles can be uniformly opened to allow for smooth inventory work and the like while also improving cold storage efficiency. Moving of the rack can be achieved by pressing a button on the rack support, by wireless remote control via the forklift truck terminal or by a superior control system [2]. The rail–less type (flexible–path) shortens installation time and can be installed in existing warehouses and in rented warehouses. Therefore, compared to a pallet type rack, moveable rack uses half as much space (offering very good utilization of storage volume), or for the same storage space offers up to 75% increase of storage capacity [3]. However, movable racks have also some disadvantages compared to selective pallet racks. Each pallet is not available in every moment – racks need to move to create an aisle. Existence of only one aisle per block implies only one forklift operating in warehouse block in the same time, making movable racks useful when inventory turnover is low [4]. To increase throughput using additional forklift(s), one can make system with two or more blocks of moveable racks, however with decrease in storage space utilization due to additional aisles. And finally, storage system with movable racks is a costly solution, with significantly higher investment cost per pallet position compared to selective pallet racks. Figure 10 illustrates one example of storage system with moveable racks.

2.2 Forklifts

In alternatives of case study analysis, two types of warehouse forklifts were used – reach truck (Figure 1) and VNA forklift – racking truck with turret head (Figure 2),

Reach truck is a classic pallet forklift for warehouses. The reach truck is a narrow aisle truck designed specifically for racked pallet storage, with requirement of aisles and cross-aisles (main transportation paths) width from 2.44 to over 3 meters [5]. Very narrow aisle trucks (VNA), as presented racking truck with turret head, have requirements for only 1.8 meters (or even less) wide aisles [5], however cross-aisles has to be 4+ meters wide. Also, this type of forklift requires guidelines for the driving within the aisles to increase safety and reduce property damage. Guidelines can be mechanical (rails) or inductive (wires in the floor). In the case of mechanical guidelines the pallets cannot be stored on the floor (ground level), resulting in some loss of the storage space and slightly increased cost of rack (additional beam). Of course, VNA turret trucks are also costly, being approximately 60% more expensive than the reach truck.

2.3 Type of facility planning

If a new storage system is planned, investment and operating costs can be minimized by optimal storage strategies which can improve the performance, utilization and operating costs. Planning any industrial production facility (including warehouse system) is a complex job and generally falls into one of the three basic categories (Figure 3) [6]:

- New planning of a factory (green field planning),
- Re-planning and/or extension of existing facilities (brown field planning),
- Dismantling of factories, also categorized under brown field planning.

![Diagram](image-url)  
*Figure 3 – Basic planning categories in factory planning [6]*

With new planning, the factory is built on a "green field site" with the maximum level of freedom. Such a high level of freedom allows the optimum factory design to be achieved. However, with this increased level of freedom comes increased complexity and planning effort because with new planning, additional tasks arise such as choosing a site. When redesigning a factory, the existing facilities and processes are modernized and adapted to market-driven changes in the production range. Re-planning is a particular challenge because of the need to allow for existing constraints such as the current infrastructure, e.g., foundations and supply and waste lines, as well as crane equipment. Extending the existing factory is always an option when the available capacity is no longer sufficient.

Case study of storage system presented in this paper was a part of a larger project (part of a medium power transformers factory, including high-voltage laboratory, assembly plant, warehouse and offices) as green field project. However, due to the fact that the primary objective of this project was construction of a high voltage laboratory and assembly plant, the dimensions of the warehouse were limited to 45 meters in length and 13 meters in width. The warehouse solution had therefore some elements of brown-field project, to fit into available space an optimal storage system.

3. CASE STUDY

The case study is presented with cost-based analysis of four different alternatives of storage system as a part of a main green field project, followed by illustration of installation process of selected solution.

3.1 Cost-based analysis

Cost-based analysis presented was done for developed four alternative solutions (variants) of storage system, derived from the various configurations of movable and pallet racks in combinations with mentioned type of forklifts. They were named as listed below:

- Pallet racks – racking truck with turret head (mechanic guidelines),
- Pallet racks – reach truck,
- Movable racks – reach truck – 1 block,
- Movable racks – reach truck – 2 blocks.

Table 1 presents costs, required space and resulted storage capacity of analyzed alternatives. First three rows represent costs of racks, forklifts and their sum. Fourth row represent required rack space of alternatives. Since the main question from investors was how much space could be saved by using moveable racks (as well as related costs), the table also shows additional spaces needed for other alternatives as well as costs of those additional spaces. In case entire available space is used, and company needs additional space in the future, it should be built or rented. So cost comparison of alternatives is done relative to an optimal space saving alternative "movable racks – reach truck – 1 block" used as a baseline.

First alternative with pallet racks and racking truck with turret head requires also additional storage space because of forklift type, needing wider main transport path, i.e. 4 meters instead of 3 meters.

Both alternatives with selective pallet racks, as well as alternative with 2 blocks of moveable racks requires additional space for racks and aisles, compared to 1 block movable rack system.
### Table 1 – Cost-based analysis of pallet and movable racks

<table>
<thead>
<tr>
<th>Cost based analysis of pallet and movable rack alternatives</th>
<th>Pallet racks – racking truck with turret head (mechanical guidelines)</th>
<th>Pallet racks – reach truck</th>
<th>Movable racks – reach truck – 1 block</th>
<th>Movable racks – reach truck – 2 blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of racks [€]</td>
<td>22 702.70</td>
<td>16 689.19</td>
<td>90 405.41</td>
<td>75 335.38</td>
</tr>
<tr>
<td>Price of forklifts [€]</td>
<td>47 150</td>
<td>29 160</td>
<td>29 160</td>
<td>29 160</td>
</tr>
<tr>
<td>Σ Price of racks and forklifts [€]</td>
<td>69 852.70</td>
<td>45 849.19</td>
<td>119 565.41</td>
<td>104 495.38</td>
</tr>
<tr>
<td>Space needed for racks [m²]</td>
<td>371.20</td>
<td>377.10</td>
<td>259.70</td>
<td>289.70</td>
</tr>
<tr>
<td>Additional space needed because of forklift [m²]</td>
<td>37.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total additional space compared to the movable rack – 1 block [m²]</td>
<td>148.80</td>
<td>117.40</td>
<td>-</td>
<td>30.00</td>
</tr>
<tr>
<td>The rental price of additional storage space (the 10-year amortization 10%/year) [€]</td>
<td>107 136</td>
<td>84 528</td>
<td>-</td>
<td>21 600</td>
</tr>
<tr>
<td>The price of building additional storage space (800 €/m²) [€]</td>
<td>119 040</td>
<td>93 920</td>
<td>-</td>
<td>24 000</td>
</tr>
<tr>
<td>Σ Price of racks and forklifts with the cost of renting additional storage space [€]</td>
<td>176 988.70</td>
<td>130 377.19</td>
<td>119 565.41</td>
<td>126 095.38</td>
</tr>
<tr>
<td>Σ Price of racks and forklifts with the cost of building additional storage space [€]</td>
<td>188 892.70</td>
<td>139 769.19</td>
<td>119 565.41</td>
<td>128 495.38</td>
</tr>
<tr>
<td>Storage capacity [number of pallets]</td>
<td>680</td>
<td>650</td>
<td>690</td>
<td>680</td>
</tr>
<tr>
<td>Difference in cost regard to the movable rack – 1 block [%]</td>
<td>36.70</td>
<td>14.45</td>
<td>0</td>
<td>6.95</td>
</tr>
</tbody>
</table>

Rental price was 6 €/m², approximately an average price for renting a warehouse around the location where production plant and warehouse are located. Renting period is 10 years, because that is rapid depreciation rate in Croatia for the warehouse. The price of building additional space (new warehouse) was 800 €/m², which was an estimated price for building one square meter of a whole project.

It could be seen from both total prices (which includes price of the racks, forklifts and price of renting or building additional storage space), pallet racks with turret head truck is the most expensive variant. In this case saving spaces with narrower aisles can’t even justify price of trucks and additional space for cross-aisle in comparison with pallet racks with reach trucks. The variant with the lowest investment cost is the one with one block mobile racks and reach truck. However, 2 block movable rack variant is very close. It is important to add that the construction site (land) was already owned, so that component of the costs has not been taken into the consideration. If that cost was included, the differences between variants would be even higher. Also the operational costs of heating, cooling and lightening of storage area were excluded from the analysis.

After presenting cost-based analysis, the management of the company decided to implement a variant with 2 block movable racks and reach. The main reason for that decision was the fact that the warehouse is divided into two parts, and in the future the throughput of the warehouse can be increased by adding the second forklift. In that situation, each of the forklifts can work in his block with no interference. Also, if the one of the engine of a movable rack is malfunctioning, the other block of warehouse can work normally. Figure 4 shows this selected alternative.
Figure 4 – The variant with 2 block movable racks and reach truck

3.2 Installation of movable rack

The main problem of installation of movable racks is a foundation that requires more attention and has higher cost regarding the pallet rack installation. The type and the size of a foundation depend on the size (length and height) and the load capacity of the rack. In this case study, load capacity of the rack was 1500 kg per pallet space. Because of that, movable racks are more suitable for green field facilities than for the brown field facilities. The main reason for this is the fact that movable racks have higher investment costs due to the need for breaking down the old floors of the warehouse. Figures 5, 6 and 7 are showing armoring of the rails, Figures 8 and 9 are showing mounted undercarriage of the movable racks, while Figure 10 shows mounted movable racks, all together illustrating the process of installation.

Figure 5 – Connection of rails with armature

Figure 6 – Armoring plate with rails
Figure 7 – Concrete plate with rails

Figure 8 – Mounted undercarriage of the movable racks

Figure 9 – Undercarriage of the movable rack
Figure 10 – Mounted movable racks

4. CONCLUSION

In this paper a case study of a warehouse with cost-based analysis of alternatives is presented. Various alternatives for storage systems in industrial applications exist. Despite well-known theoretical characteristics (advantages and disadvantages), to properly evaluate solutions various cost related and non-cost related factors should be taken into account. However, not many papers with case studies appear in literature. In our opinion such papers provide great value to practitioners, potential investors and designers, as well as valuable educational information to students.

Paper presents a real case project with conducted cost-based analysis of four alternatives for pallet storage. The main idea behind analysis was to evaluate and justify system with moveable racks, according to the main characteristics of space saving. The presented analysis shows how reduced building costs (or costs of renting additional space) can justify higher investment costs of movable rack system. Additionally, decision by the investors also shows how some other factors may influence decision. Although the variant with one block movable racks was cheapest, the management of the company decided to accept the variant with two block movable racks. The main reasons for that was the possible risk of malfunctioning (and entire warehouse blocked) and possibility to increase throughput of the warehouse by easily adding the second forklift.

For further research, work with this case derived idea of possible development of a decision-support model for determination of storage system, given the parameters such as the size of the warehouse, number of blocks, price of the racks, forklifts, buildings, land, etc.

Also, a rail-less movable rack has not been taken into consideration in this case study. This is another topic that would be interesting to analyze. While movable racks with the rails are more suitable for green field constructions regarding the problem of the foundation, rail-less construction for this type of the rack is also suitable for brown field warehouse construction (installing moveable racks in existing warehouse).

5. REFERENCES

KAIZEN APPROACH TO SUPPLY CHAIN MANAGEMENT:
FIRST STEP FOR TRANSFORMING SUPPLY CHAIN INTO
LEAN SUPPLY CHAIN

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Abstract
This paper provides evidence on how the use of Lean management approach and one-day Kaizen workshop can help to discover root-causes of problems appearing in the supply chain, particularly in this paper focusing on late delivery. In addition, the well-known Quality concepts such as Ishikawa diagram and $5 \times Why$ may enrich the Lean Management as applied to the supply chain. Also, this paper shows that problems in the supply chain are sometimes caused by company’s internal procedures and its internal inefficiency. A case study from suspension and joining equipment factory in Croatia was used to support the research. At the end a simple solution for the discussed problem was proposed.

Keywords: Supply chain, Lean management, Kaizen, Ishikawa diagram, $5 \times Why$

1. INTRODUCTION
In the last few decades, almost everything related to production and business has changed: the world became more complex and the time became extremely precious. World becoming more complex means that demand on mass customized products is constantly rising, just as the need of being first on the market, and responding fast to changes. Those two factors brought significant changes in the way of operating a company, forcing it to shrink planning cycles and increase its efficiency. Less efficient activities are being outsourced and there is hardly any company left that is doing the whole process of transforming materials into goods for end costumer, making supply chains more and more important. A key feature of present day business is that supply chains are the competitors, not companies themselves, and the success or failure of supply chains is ultimately determined in the marketplace by the end consumer. That is why a lot of effort has been given to raising of supply chain efficiency.

1.1 Supply chain
A supply chain is the alignment of firms that bring products or services to market. A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves.

As the supply chain connects a lot of entities, the coordination between them is needed for smooth operation of the chain. Therefore companies employ supply chain managers whose jobs include determining transportation vendors, credit and cash transfers, suppliers, distributors, accounts payable and receivable, warehousing and inventory, order fulfilment, sharing customer, forecasting and production information. The objective is to build a chain of suppliers that focuses on maximizing value to the ultimate customer. If the company is using goods and services from outside sources it needs to choose one of the supply-chain strategies such as: negotiating with many suppliers, long-term relationships with few partners, vertical integration, keiretsu, developing virtual companies that use suppliers on an as-needed basis. Choosing correct strategies is crucial for successful business.
Sometimes companies in the chain strive to maximize their own business by seeking for a local optimum, but changes in their business can cause disruptions such as bullwhip effect in the whole chain. Bullwhip effect is defined as: distorted information from one end of a supply chain to the other that can lead to tremendous inefficiencies: excessive inventory investment, poor customer service, lost revenues, misguided capacity plans, ineffective transportation, and missed production schedules. One of the possibilities to minimize a risk of bullwhip effect is implementing Lean management across the supply chain.

1.2 Lean Supply Chain

Lean manufacturing has been implemented by many companies in the world through different industries. But, for the full effectiveness, the Lean production system must be extended down through the supply chain. On the other hand it has to be stressed out that it is impossible to implement Lean management in a company and expect that this is not going to affect the whole supply chain. The Lean Supply Chain means to identify all types of waste in the value stream of supply chain and take steps to eliminate them to minimize production lead time.

The objective of this paper is to determine whether the Lean management approach to supply chain, together with one day Kaizen workshop and use of tools such as Ishikawa diagram and 5×Why can help to discover root-causes of problems appearing in supply chains. Research was conducted as case study research in a suspension and joining equipment factory in Croatia which is producing electrical equipment for high voltage transmission lines. The research focuses on two main aspects: (1) when faced with complicated problems in supply chain, such as delays in order fulfilment, can companies use Lean tools to find root-causes of the problems and (2) are simple Lean management tools good enough for solving complicated problems like delays in order fulfilment.

As a part of the analysis carried out the following research questions are answered:

i. How can one day Kaizen workshop and use of simple analyzing tools such as Ishikawa diagram, 5×Why help to determine root-causes of problems appearing in supply chains?

ii. Where are root-causes of problems appearing in supply chain, inside the company or outside?

In particular, the research focuses on the use of one day Kaizen workshop to increase an understanding of importance of using that approach in identifying root-causes of problems appearing in supply chain.

Following these questions, we tried to formulate valid conclusion on how one day Kaizen workshop followed by analysis of results can lead to discovery of root-causes of problems, in our case late delivery, in supply chain.

2. METHODOLOGY

Case study research methodology was used. A single case study was chosen because of the exploratory nature of the study. Using single case design allows an increase in the quality and quantity of data obtained. Researchers were involved in the planning, preparation and execution of the one day Kaizen workshop. One of the researchers was facilitator of the workshop and other two were observing the process, and collecting the data. This particular approach to research enabled a deeper understanding of the processes in the company but also relationships between different departments involved in the supply chain as well as the nature of their communication.

Before the start of this research project, researchers were already involved in the activities of process optimization in the company. During the interviews which were conducted as part of improvement activities, late delivery was detected as one of the main problems. Going deeper through the analysis and interviewing employees in the production planning and technology department, it was noticed that there is a problem with later delivery of raw material which is then leading to late delivery of final product. As material supply is part of supply chain, it was decided that new research project will be done analyzing the possibilities of implementation of Lean tools while analyzing the whole supply chain. After the literature was reviewed it was concluded that one day Kaizen workshop approach is going to be used to analyze the possibilities of improvements in the supply chain with the aim to find root-causes of late delivery. Second reason why one day Kaizen workshop was chosen was that employees were already familiar with the concept. The settings of Kaizen workshop part of the paper are described in details in the case study. After the workshop, results were
analyzed and conclusion was given that Lean tools, in our case, one day Kaizen workshop, can give solid framework to search for root-cause of problems appearing in the supply chain.

3. CASE STUDY

Case study was conducted in suspension and joining equipment factory. The company faced a serious problem of delivery delays to its clients that caused serious expenses. A goal was to find root-cause of this problem and later an easy adoptable and affordable solution to that problem. At the time of research, the company was at the very beginning with Lean journey. It was at the stage of learning about Lean and implementing first Lean tools.

Top management, as well as shop floor management, both were convinced that suppliers have the main impact on delivery delays. Delivery delays of supplies and poor quality supplies were common. Supplies delivered with delay or poor quality, both lead to production start delays, and eventually to late delivery of products to company's clients. At the same time, strategy for choosing a supplier was price – the cheapest supplier got the job. Other important data as estimated delivery, time or quality of delivered supplies were not considered. Still, a thought was, that supply chain should be analyzed to find a solution to a problem.

A first task was analyzing existing supply chain and its efficiency, by conducting metrics suggested by O. Planned metrics included customer service and internal efficiency, with metrics such as on-time completion rate and on-time delivery rate, value of late orders and number of late orders, number of warranty returns and repairs, inventory value, inventory turns, return on sales. Statistics and available data were used to gain information, as well as interviews with employees from different departments. Unfortunately, it was found that, even though employees are aware of existing problems, there were no data records available for some important things such as accurate inventory lists and its value or a list of on-time delivery dates. After this part, it was clear that delivery delays problem is something complex. As the company was already implementing Lean philosophy and had plan of implementing a Lean supply chain, the idea of using Lean for solving mentioned problem seemed like a next logical step. Kaizen was recognized as a powerful tool by top management, and delivery delay problem was chosen as a first problem. This is where Lean and supply chain management were matched.

3.1 Kaizen workshop

Kaizen workshop with a delivery delay as main problem was planned. As it was already known that it is a complex problem, and believed that the reason lies in the supply chain, employees from different departments involved in supply chain were chosen for this workshop. Representatives of purchase, production, inventories, sales, IT and planning were all involved. Main goal was to find a cause for main problem, and try to find a solution for it. Usual tools were used – Ishikawa diagram, brainstorming and 5×Why. The workshop started with a short explanation on tools: Ishikawa diagram, brainstorming and 5×Why. Short introduction to the problem was done by the facilitator as well as the objective of the workshop: find the root-cause of late delivery and find one feasible solution to this problem. After as-is analysis, possible solutions for improvements were discussed. One solution was chosen and discussed in depth as well as its to-be analysis.

3.2 Ishikawa diagram

Ishikawa diagram, also known as Fishbone diagram or Cause-and-effect diagram is considered as one of the seven basic tools of quality control. In our case study, Ishikawa diagram was used for the representation of major problems and their root-causes. Even though top and shop floor management were convinced that main cause are suppliers, everyone else had its own opinion about causes and many of them were found very easily. At first, every person was filling out its own Ishikawa diagrams, which were then discussed, and suggestions with the most votes were taken into new Ishikawa Figure 1.
After a long discussion, it was agreed that this four reasons are root-causes for delivery delays to company's costumers (Table 1).

**Table 1 – Main causes for delivery delay**

<table>
<thead>
<tr>
<th>Root Cause</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive supplies</td>
<td>Not only did it take a lot of space, so additional handling was needed for current projects, but they also meant a lot of frozen capital. That way, a flow of money was prevented, what meant less capital for investing into relationships with suppliers.</td>
</tr>
<tr>
<td>Ineffective communication</td>
<td>Communication was slow, sometimes taking even few days for information to reach a person in neighboring office. Information system was also not making information flow easier, in contrary, two different systems were used but information were not exchanged between departments, what made it very hard for production planning. For example, a planning department never got a final information on supply delivery date from purchasing department. Neither literary, neither from software, what made accurate planning almost impossible and eventually led to gaps in production.</td>
</tr>
<tr>
<td>Complicated purchasing procedure</td>
<td>Purchase was a large problem as the procedure took sometimes up to a month for allowing contracts with suppliers. It is a procedure shown on Figure 2 that involves many people. At first, a design department creates a list of supplies needed. That form has to be signed by three different employees just to get to the purchasing office and to be converted into order-formed paper that again needs to be signed by two top managers before it is signed with the supplier. Physical papers were used and they were brought to each person's office. Up to 50 different papers were used daily. Since this procedure sometimes takes up to a month, it is obvious that it leads to late order that demanded unrealistic short delivery dates of supplies. Since suppliers’ delivery policies usually have long estimated delivery dates, it made significant effect on company's production as well. Later production starts usually lead to production finish delays, and finally, late delivery to customers as well.</td>
</tr>
<tr>
<td>Suppliers</td>
<td>Just one of four mentioned causes involved suppliers. Supplier related problems such as choosing a supplier by price or their delivery delays and incorrect deliveries were recognized. It was clear that no deeper relationships with suppliers were built.</td>
</tr>
</tbody>
</table>
6.2 Brainstorming

Observing that suppliers cause only one quarter of delivery delay problems, it became very clear that focus has to be on improving company's processes. Using a brainstorming method, a lot of ideas about what and how should be improved were given. They were discussed, and next it was concluded, that the main thing that should be done is shortening a process before purchase.

6.3 5×Why

Finally, 5×Why technique was used to find a source of paper-allowing delays. It was discovered that papers sometimes stay too long in the offices just because a person didn't see the new ones coming.

![Figure 3 – 5×Why work-sheet](image)

As a conclusion to the workshop, the idea of creating an unique place in the factory for managing purchase process was made, Figure 4. It is important, that this is a simple solution that is not changing procedure and therefore not considered as a radical solution. It is only helping to speed up the existing process. A board consists of cases for each person involved into process. Upper the case, a name is written, and between the name and the case, it is left some space for colored card. Red means that person's case is full, so it has to stop, open it, go through papers, sign them and put it in next person's case. Than it also puts green (meaning a free case) to its case and red card to next person's case (meaning that attention is needed).

Even though a board is a great idea to speed up the process, because no one wants to have a red card under his name, it has some disadvantages, such as supporting complicated procedure.

Also, there is still no backup plan for a case of responsible person being absent. These are still things that need to be sorted out. This is why this board is considered only a temporary solution that will show how time and money were easily wasted. It is also expected that cost benefits brought by using this board will
stimulate and lead the company management to more improvements such as developing background plans, implementing electronic solution to this procedure, developing ERP system's properties, developing less complicated procedure.

Figure 4 – Visual board for managing purchase

Solving this problem does not only lead to reducing wasted time, it is also a first step to building relationships with suppliers and therefore a first step to Lean supply chain.

7. CONCLUSION

As companies compete on the level of supply chains, those supply chains have to be efficient and thus companies have to analyze their processes with the aim of finding new possibilities for improvement. This paper showed how Lean management approach, one day Kaizen workshop and use of simple analyzing tools such as Ishikawa diagram, 5×Why can help to determine root-causes of problems appearing in supply chain. Particularly, it was shown that facilitated workshop, usage of Ishikawa diagram and 5×Why helped to discover root-cause problem for the late delivery of products. Although top and shop floor management thought that the problem is caused by suppliers and their late delivery of raw material, it turned out that the main problem was inefficient procedure of confirming purchase orders. A simple solution as a conclusion of the workshop for the problem was also proposed. Solution is shown on the Figure 4. Lean management approach together with one-day Kaizen workshop proved to be also helpful in determining that the root-causes of problems in supply chain can appear inside the company. Therefore, if the company strives to achieve Lean supply chain, first thing to be accomplished is improvement of its own processes. Thus, before the Lean supply chain, Lean company is the first goal to achieve.

8. REFERENCES

ENVIRONMENTALLY WASTE MANAGEMENT: A MODEL FOR POST-CONSUMER WOOD HANDLING

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Abstract
The current practise of municipal wood products waste collection is to collect it along with other bulky items. However, recovery or disposal of post-consumer wood is possible in many different ways. Therefore there is a need to improve post-consumer wood treatment at the end of its life-cycle. The costs of fresh wood material is increasing and lack of wood material in the future can be expected. Furthermore there is the need to accomplish EU directives. Additionally, current collection practice is inconsistent and not transparent. In this paper possible improvements will be presented. Many suitable solutions for the treatment of municipal solid waste can be found in various models for decision support, therefore our purposed model for management of post-consumer wood is derived from these models. Research into the design and development of a post-consumer wood as municipal waste model (OLKO) will be described.

Keywords: post-consumer wood, decision support, life cycle assessment, LCA model, OLKO

1. INTRODUCTION
From the mid 20th to the beginning of the 21st century mankind was progressing extraordinarily, making large profits and producing goods on a massive scale, which has relied heavily on intensive use of primary material resources¹. Nowadays the consequences of these actions are twofold: On one hand, there is an increasing lack of natural resources for material and energy use, while on the other economical and ecological problems are developing in connection with an increasing amount of municipal waste². The twofold nature of this problem is the main reason for the increasing interest in the economy and science of waste materials and their reuse.

For this purpose the European Union (EU) from 1975 onward, when the first Council Directive of 15 July 1975 on waste (75/442/EEC) was accepted, started unitary legal management of this problem [11, 59]. Nowadays this area, in compliance with the newest Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives, is managed progressively and transparently [16]. Separate collection of paper, glass, plastics and small metal wastes has already been established. Directive 2008/98/EC in Article 11 strives to promote product reuse, preparation for reuse activities, and high quality recycling activities [16]. To this end, it calls for the establishment of separate waste collection for common recyclable materials, and where technically, environmentally, and economically practicable solutions for other materials, such as post-consumer wood.

¹ Birkeland [7] reports, that the use of the resources in the USA has doubled every twenty years in the previous century.
² Cities of the world currently produce 1,3 billion tons of municipal waste annually. But the number is supposed to, especially in countries with low and middle incomes, because of the consequences of the population growth, increasing urbanisation and socio-economic development rise to 2,2 billion annually by the year of 2025 [26].
The collection of post-consumer wood in our country is managed in compliance with multiple regulatory provision acts [65-67] depending on the source of origin. Because of unevenly dispersed resources the collection remains very inconsistent. This means that in resource production there are sometimes unsuitable aggregate containers that would collect post-consumer wood as separate fraction with which the economy could deal more systematically, economically, and efficiently. In our country the final handling of the post-consumer wood is managed with multiple regulatory provision acts [1, 65, 66, 68-72]. Because of the complexity of legal basis, post-consumer wood is not managed in an unified manner. Different ways of processing post-consumer wood contribute differently to achieving the environmental, economical, social and political goals of the EU.

Because of the expected lack of wood and higher prices of raw wood materials in the future, it is necessary to provide appropriate collection and recovery methods for post-consumer wood. Therefore model which will provide future projects with a foundation for effective utilization of post-consumer wood is required.

Because of the expected lack of wood and higher prices of the fresh raw wood materials in the future, it is necessary to provide the appropriate collecting and recovery and create a model which will serve for producing the projects of effective utilization of the post-consumer wood.

2. PREVIOUS RESEARCH AND DISCUSSION OF THE SCIENTIFIC PROBLEM

2.1 Detailed classification and definition of post-consumer wood

Post-consumer wood is a product derived from diverse activities. The European Waste Catalogue And Hazardous Waste List [20] merges the wood wastes into the same category and designates them with numeric nomenclature according to the source of the waste into groups 15, 17, 19 and 20 [30, 38, 43, 47]. We can separate post-consumer wood according to the collection jurisdiction, namely the post-consumer wood that is municipal waste (MW) and post-consumer wood that is not municipal waste (NMW). For purpose for this research we will focus on post-consumer wood (MW).

Even though it has been noted that the total quantity of post-consumer wood (MW) gathered with municipal waste services has grown rapidly [61], in addition to the price increase for raw materials in our country [60] and abroad [70], there are no signs of post-consumer wood (MW) being collected intentionally and separately. This may be due to the increased fuel consumption and working hours for employees associated with collecting larger fractions at the source of origin, as suggested by Taskanen & Kaila [64].

Collection of the post-consumer wood (MW) in our country is regulated in compliance with A Decree on the management of separately collected fractions at doing public service of management of municipal waste [51]. Post-consumer wood (MW), which is classified as part of the so called "other municipal waste" subgroup, is in our country collected in different ways: (1) In the context of a public service the collection of the bulky waste at the collection places for the bulky waste must be assured at least once a year, regardless

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1 In the near future, presumably from the year 2012 until the year 2050, according to the estimates of experts of the European union of papermakers (CEPI) a shortage of wood is expected. The main cause for this will be large growth in the demand for wood, paper and wood materials in China and India where they are already facing shortages of wood [27].

2 Among the post-consumer wood (MW) we reckon the package waste that is a municipal waste (KOE) (15) and post-consumer wood from the households (20). It is collected solely by the executants of the commune public services (IJS).

3 Among the post-consumer wood (NMW) we reckon the package waste that is not a municipal waste (NKOE) (15), post-consumer wood from the construction work (17) and post-consumer wood from the waste management machines (19).

4 The total quantities of wood fractions, which were collected with public waste services, have been recorded in the year of 2012 as 24.017 tons which is almost 60 % more than in the year of 2007 (9,922 tons). This means 11,7 kg of wood waste per inhabitant in the year of 2012 [61, 63].

5 During the period between 2005 and 2009 price growth of 39 % for round softwood, 37 % for sawlogs and softwood veneer, 81 % for pulpwood and hardwood panels and 14 % for other industrial softwood has been detected [60].

6 Van Riet [73] reports, that the raw material prices for paper industry, construction sector and manufacturing of furniture have on average risen from 20 to 25%.
on the number of the inhabitants, (2) exceptional cartage by the executants of the public service on the costs of the client or, (3) independent transport by the users to the collection centre.

That means that: (1) the quantities of the post-consumer wood are being neglected (MW), (2) the post-consumer wood (MW) is merged with the rest of the bulky waste (illuminants, shaders, bathroom equipment, carpets, mattresses etc.), which do not have woods' value, (3) the collection is inconsistent and mostly left to the users themselves, (4) the material can be left to natural degredation for a considerable amount of time, (5) the wood and energy industries cannot maximally make good use of all the available material.

Final managment over post-consumer wood (MW) is connected with recovery or disposal [16], disposing on disposal ground [12] or combustion [14, 15, 17]). Because the law basis is widely interpretable the post-consumer wood (MW) is not being managed in a unified way [31, 34, 52, 56, 59, 73]. Processing of the post-consumer wood (MW) contributes differently to achieving environmental, economical, social and political goals of the EU.

According to studies published in the Annual report (2003-2004) of European Panel Federation (EPF) the added value of wood products was calculated to be 1.044 EUR/tonne dry as compared 118 EUR/tonne for fuel use. Moreover, wood based products, on average, generate 54 man hours/tonne of dry wood, whereas energy use generates only 2 man hours/tonne [46, 73].

In solid form wood stores carbon [4, 25, 44], and when used as an energy source replaces fossil fuels with a renewable resource [8, 9, 35, 54] it mitigates climate changes.

Current political actions do not yet recognize the carbon storage capacity wood products as an important element in fighting against the climate change, but they define it as an energent [53]. The use of post-consumer wood (MW) for the production of energy importantly contributes to achieving two main political goals of the European Union. It encourages use of renewable resources of energy in the final gross consumption of energy for 20 % until the year of 2020 in compliance with Directive 2009/28/EC and contributes to achieving the emission reduction objectives in the EU, as it is defined in the Energy Roadmap 2050, which predicts unified reduction of the greenhouse gas emission for 85 % until the year of 2050 [17, 23].

We can define the existing method of post-consumer wood (MW) management as: (1) uneconomical; (2) environmentally unfriendly and unsustainable; (3) non-compliant with the pursued political goals of the EU. That is why it is necessary to prepare a suitable model and define the environmental and economical processes.

2.2 Decision support models in the logistics of management with municipal waste

Logistics often makes use of modelling when defining the most appropriate way of handling certain processes. A model is representation of an object, system or idea in some form, other than that of reality itself [55]. Most of the municipal waste models identified in the literature are decision support models [49]. Morrissey & Browne [49] and Karmperis et al. [33] divide them into three groups: (1) based on cost benefit analysis, (2) based on multicriteria decision making, and (3) based on life cycle assessment (LCA). A combination of all those are possible too [6, 10, 41, 32] but it is a subject beyond the of this research. The narrower scope of this research will be decision support models based on LCA.

The LCA is an analitical tool for sistematic and objective evaluation of all the essential influences that the product, a service or a subject has on the environment inside of it's life cycle [37]. In the compliance with the ISO 14040 [28] and 14044 [29] standards, the products can be arranged into four different categories, namely: (1) production of raw materials, (2) manufacturing, (3) the use and maintenance, (4) recycling and waste managment. Because the LCA is dedicated to the comparison of different alternatives, different wood products that we can classify as municipal waste after the end of it's lifetime, have been researched for this purpose. E.g. pallets were being researched in Singh & Walker [58], Lee & Xu [42], Barthel & Albrecht [5]; particle boards in Werner [74], Rivela et al. [57]; furniture in Nedermark et al. [50], Kutnar & Tavzes [36].

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9 The advantages of the LCA models, which are being used in the systems of managing waste, can be summarized in this manner: (1) There are long-term benefits in environmental protection from different options, e.g. waste recycling instead of landflling; (2) A LCA model allows for both environmental improvements and economic benefits; (3) All emissions into land, water and air can be quantified; (4) All effects arising through material consumption on humans and eco-systems are estimated and evaluated; (5) Alternative scenarios of an examined waste management strategy can be identified and compared, in order to distinguish the most suitable scenario [33].
LCA is an analytical tool for systematic and objective evaluation of all the essential influences that a product, service or entity has on the environment during its life cycle [37]. In compliance with the ISO 14040 [28] and 14044 [29] standards, products can be arranged into four different categories: (1) production of raw materials, (2) manufacturing, (3) use and maintenance, (4) recycling and waste management. Because the LCA is dedicated to the comparison of different alternatives, different wood products that we can classify as municipal waste after the end of its lifetime have been researched for this purpose. E.g. pallets were being researched in Singh & Walker [58], Lee & Xu [42], Barthel & Albrecht [5]; particle boards in Werner [74], Rivela et al. [57]; furniture in Nedermark et al. [50], Kutnar & Tavzes [36].

In the field of services in which waste management is included, modelling has been ongoing with the support of LCA from the early 90's onward [24, 49]. Research has mainly focused on services or waste management within the "cradle-to-grave" [45] or "bin-to-grave" [13] paradigms. Currently there are more than 50 models available in Europe, all on the basis of the LCA [21]. There are even more worldwide, with different usabilities and functionalities, licence restrictions and costs [24]. We separate them into generic and dedicated models [40]. Despite that, these kind of decision support models have not found their permanent place in the municipal public service in waste management [22]. Possibly because, as Winkler & Bilitewski noted [75], some were proven to be too complicated, inflexible and hard to explain and above all incomparable for everyday use. In the comparative analysis of Winkler & Bilitewski [75], which was based on the quantitative assessment for the city of Dresden in Germany, 6 LCA models selected for the same input values provided very different and contradictory results. Their comparative work has been continued by Gentil et al. [24], who were finding out why and where those differences came from.

To improve existing models, which fall short of the needs of society we will prepare the following: (1) the newest version of the model, (2) apply the model to a certain region in Slovenia, (3) adjust the model for Central Europe, (4) include external and internal transport, (5) exclude the possibility of removal or disposal of wood in the landfills from the model.

3. RESEARCH METHODS

3.1 Model description

For the purposes of our research we will develop a model for post-consumer wood (MW) and name it OLKO. We will do the computer-supported modelling in Microsoft Office Excel®. The OLKO model will be composed of multiple submodels which represent the managing of the post-consumer wood (MW) in a certain environment at a certain time (Picture 1). In modelling we will: (1) choose the appropriate system for ladling the wood waste, (2) compose the calculations with formulas, (3) prepare generally valid normatives and standards and (4) regarding the emission factors from the Ecoinvent 2.0 [19] database evaluate all the energetic processes in management of wood waste in every phase of handling.

Because of the better economic statements we will model the collection according to the system "bring" even though we know that the "kerbside" model offers a little more quality service of collecting the waste. Management will be based on the Decree on the management of separately collected fractions at doing public service of management of municipal waste [51], where the estimated quantity of the post-consumer wood on a single inhabitant will be conditioned by the number of the assembly containers in a certain settlement and not by the maximum allowed distance from the places of the residences.

Every phase of managing of the post-consumer wood (MW) will be composed out of two compounds: (1) calculations with formulas and (2) generally valid normatives and standards. Process of modelling the management of wood waste demands a mergerence of both compounds. In all of the mentioned processes these compounds set different specifications, which will be fully economically and environmentally evaluated in the continuation. This will be accomplished with the use of the emission factors from the Ecoinvent 2.0 [19]

10 Waste management means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker [16].
11 (slov: odslužen les, ki je komunalni odpadek/ engl. post-consumer wood that is a municipal waste).
12 Kerbside collection would provide the highest recycling rate, 31 % compared to 25 % in the baseline scenario, but bring schemes with drop-off containers would also be a reasonable solution. Collection of recyclables at recycling centres was not recommendable because the recycling rate would decrease to 20 % [39].
First part will serve for the use of forms or models for calculation of the specific values and the second part for incorporation of the mentioned elements into the whole. We will develop formulas and normatives with standards with the help of literature and with a query with the experts in the communal service and experts in the Ecoengineering group in Brest furniture d.o.o Cerknica company.

Computer-supported model will serve for a realization of the system for collecting the secondary wood materials in the collection centres of post-consumer wood (MW), takeover and alteration, calculation of influences that the processes have on the environment and the calculation of the costs of dealing with wood waste MW. Input data into the modelling will be (1) estimated collected quantity of the post-consumer wood (MW) (kg); (2) transport route (km) (3) the energy needed for the transport and alteration (MJ) and (3) estimated costs (EUR). Output data will be: (1) emissions (kg/MJ), (2) acquired energy (MJ); (3) time (sec) (Figure 1)13.

![Diagram of collecting and analysing post-consumer wood](image)

**Figure 1** – Model of the collection and analysing the post-consumer wood (MW)

### 3.2 Description of the submodels

Submodel in the OLKO model is composed out of two major compounds, namely (1) collecting and sorting and (2) recovery. Collecting is about the transport of the post-consumer wood on short distances. In this phase we will divide the transport-personal vehicles of the waste owners [62] from the point of origin (A) to the estimated place of the container (B) and hoist-trucks (self-loaders)14 of the public service collectors, who will do the transport from place of the container (B) to the collection centre (C). Autonomous cartage by the owners of the post-consumer wood MW from the place of the origin of waste (A) to the collection centres (C) will not be addressed in this research because we predict that the people will drive waste to the closer places.

Sorting of the post-consumer wood (MW) takes place in compliance with The Regulation on waste [65] and Directive 2008/98/ES [16]. This means that the post-consumer wood (MW) will be separated in the collection centres according to (1) source of the wood materials (classification number), (2) contamination and (3) quality. Criteria for the definition of the risk is estimated (1) qualitative: based on the classification system of the waste (dangerous or harmless), in compliance with the Annex 4 of this Regulation on waste [65], (2) quantitative: based on the properties on the account of which the waste is being classified among the dangerous waste (H1-H15), in compliance with the Annex 1 of this Regulation on waste [65].

In the first compound the takeover of the post-consumer wood (MW) is being classified as the function, which represents the transport of sorted and completely dismantled post-consumer wood (MW) from the collection centres (C) to the point of the collecting in the recovery centre (D). Because transport of post-consumer wood (MW) with more efficient specialized vehicles – tilt-frame container15 – is mostly being used in this

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13 On the Figure 1 marked with all the arrows to the right.

14 Special municipal vehicle, which in the process of exploitation loads the containers of the capacity 6-12 m³. Mostly in use for transport of the materials on smaller distances or from place of containers to the collection centres.

15 Special municipal vehicle, which in the process of exploitation loads the abrol containers of the capacity 20-35 m³. Mostly in use for transport of the secondary materials on longer distances or from the collection centre to the final recovery or disposal.
phase, these trucks will be addressed in details. Even though there are more collectors and processors
evident in compliance with the ARSO [2, 3] report, we will do a simulated model, which will illustrate a
takeover of only one, because it will be easier for analysis this way.

The processing compound of the post-consumer wood (MW) covers transport and recovery. From the point
of pooling the wood (D) until the point of processing it (E) there will be an ongoing internal transport with
cranes and dredgers. At the place of alteration the wood material will be processed into wood chips (R 12)
[16, 65], which will be classified according to their purity as 19 12 06 or 19 12 07* and be treated separately
because of their dangerousness. Processed wood chips will be transported with a dredge, blowpipe, rail or air
conveyor and will be appropriately stocked in the silos (R 13) [16, 65]. From the point of the stocking (F)
the wood chips will be transported either into the furnace (G) for energy generation (R 1) [16, 65], or into the
production of the particle boards (H). For the purpose in searching for the best environmental possibilities
and recording the effects of the individual use or recovery, different scenarios of recovery will be prepared (A-
D). While doing this we will, in different combinations, distinguish repeated use of wood, combustion and
recycling for the production of particle boards. High quality harmless post-consumer wood will be used once
again, quality wood will be recovered for the production of particle boards whilst the low-quality wood will
be recovered for energy purposes. Quality dangerous wood will be used once again whilst the low-quality
wood will be recovered for energy purposes.

4. CONCLUSIONS

In the past waste was not treated as a material. Time and irregular way of managing of renewable and
unrenewable resources has brought us to the point where we try to reuse the waste products as best as we
can. Wood can be classified among those. One of the effective tools for the decision support is the LCA. The
LCA was addresses at researching the individual or multiple phases from the perspective of a product or a
waste. The addressing of the LCA was in a lot of cases dedicated to the analysis of the municipal waste from
the perspective of service. It is detected that among the latter some models exist, which include wood in the
fractions. Despite that: (1) models are of a older implementation, which does not give the comparable results,
(2) studies of the case, which contains the post-consumer wood with the modelling, cannot be found; (3)
models do not address the qualitative standards for the post-consumer wood, which are necessary for larger
exercising of the hierarchy of waste in Directive 2008/98/ES [16], (4) models are not adjusted for the
geographical area of the Central Europe, (5) models do not include all of the external and internal transport,
(6) models include dumping of waste on the landfill.

Because the existing models do not meet the modern requirements connected to the management of post-
consumer wood (MW), we will in our analysis prepare the following: (1) the newest version of the model,
(2) articulate the model OLKO to a certain region in Slovenia, (3) Classify the qualitative standards for the
post-consumer wood which are neccessary for larger exercising of the hierarchy of waste in Directive
2008/98/ES [16], (4) adjust the model for Central Europe, (5) include external and internal transport in the
model, (6) exclude the possibility of removal of disposal of wood in the landfills from the model.

We will add the economical component to the environmental LCA. For this purpose the OLKO model with
submodels will be created, which will include a management of the post-consumer wood (MW) with the
system limitation "from bin-to-grave". In the collection scheme we will choose the principle "bring", with
which we anticipate to bring the collectors in the research better economical results than "kerbside". This
kind of modelling with OLKO represents a more comprehensive approach at addressing the problematic
and significant progress in the field of management of post-consumer wood (MW), which will represent a
contribution to the goals of the effective alteration and utilization of wood that is defined in the Action plan
"Wood is fine" [1]. The OLKO model will be a computer application that will serve as an assistance to
academic and expert public. Because the component of an environmental evaluation is included the
researchers, who research processes of the alteration of the remainders and post-consumer wood, will be able
to use it as a model and with that they will also reward their scientific-research work. In the final phase the
model will be available in the practical work which is involved in management of waste or with secondary
materials, for which it is also designed for and which can ensure the return of quality materials into a new
production. Beside that, the model OLKO will also represent a certain base for other collectors of the waste.
The scheme of the model will be adjusted in a way that it will enable practical application in our country as
well as abroad. The purpose of developing a decision-making model for the post-consumer wood MW on the
basis of LCA will be the development of a new methodology of decision-making at recovery, which will be
enhanced with economic indicators. The OLKO model will be developed on the basis of the actual reality and will be applied in the actual environment. Its transparency will reflect the objective evaluation of the management of post-consumer wood (MW).

In the era of material deficiency, more expensive natural resources, increased unemployment and bigger and bigger environmental challenges, connected with satisfying the political goals of the EU, OLKO proves to be a major strategical element. With more consistent and more transparent processing of the post-consumer wood we can exercise the hierarchy of managing of the wood waste in a better way and ensure more quality materials in the production and make a step forward in researching and science.

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