



**LOGIC 2013**

Belgrade, Serbia  
28-30 November

**Editors**

Milorad Vidović  
Milorad Kilibarda  
Slobodan Zečević  
Momčilo Miljuš  
Gordana Radivojević

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**Proceedings of the  
1<sup>st</sup> LOGISTICS  
INTERNATIONAL  
CONFERENCE**



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Belgrade, 28-30 November, 2013

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**1<sup>st</sup> Logistics International Conference**

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Belgrade, 2013

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## Preface

The idea of organizing a logistics conference was in correlation with the Logistics department alumni's meeting, that is held traditionally every last Saturday in November. During the 2012 alumni's meeting, our colleagues and friends, most of which are now distinguished professionals, scientists, managers or officials in logistics and related areas, have given us a decisive impulse and encouragement to run the conference in 2013.

Thanks to one of the youngest researchers at our department, the conference holds, I believe, an impressible and penetrative acronym "LOGIC", which is at the same time associative and deeply tied with the essence of logistics.

This way, by organizing the 1<sup>st</sup> Logistics International conference we have made one step ahead in further popularization and spreading of the ideas from this emerging area, while at the same time reestablishing the practice of our department in organizing logistics conferences, which goes back to the '80s.

The conference has tried to materialize the idea of becoming a forum and a meeting place where participants from universities, institutes and companies from different logistics related fields may have the opportunity to collaborate and exchange ideas.

Have we succeeded? Active participation to the conference took about 170 authors, speakers and discussants from 14 countries. The program committee, based on the reviewers' suggestions, has accepted 58 papers from 133 authors that were presented through 10 conference sessions. A specific program session "Logistics – Best practice", launched as an attempt to connect theoretical knowledge and academic research with the real problems in logistics, providing a synergy of theory and practice, comprised three workshops with 19 presentations and more than 50 interested participants and discussants in each of the three workshops.

Based on those numbers, the quality of presented papers and presentations, respecting unanimous opinion of conference participants, induced also by the beauty of the city of Belgrade itself, I am very pleased to have the opportunity, in behalf of the Program committee, to evaluate the LOGIC 2013 conference as very successful!

To make this event successful, besides the effort of participants, authors and organizers, we have received immense help from the Ministry of Education, science and technological development of the Government of Republic of Serbia, from our general sponsor, company "Milšped", and numerous sponsors: "Kuehne+Nagel", "Cargo-partner", "Delta transportni sistem", "Standard logistics", "Bas Beograd", "Rauch", "Hellenic Coca-Cola", "Carlsberg Srbija", "Nestle", "Doncafe", "Lasta". We would like to express our sincere thanks and appreciation to all of them.

The conference proceedings book is now here. It is composed of seven parts referring to each of the conference sessions. To judge its quality is left to the reader, but the book provides an opportunity to have insight into our thoughts on logistics.

With the hope that the next conference will be even better, we warmly invite you to meet again and exchange ideas on the second LOGIC conference in 2015.

Belgrade, December 2013

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**Part I**

**OPTIMIZATION AND  
MODELLING IN LOGISTICS  
AND TRANSPORTATION**

# A METAHEURISTIC ALGORITHM FOR THE ANTI COVERING LOCATION PROBLEM

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**Abstract:** In order to improve performances of logistics systems, one of tasks is to properly locate relevant logistics objects. Some of these tasks can be modeled as the Anti-Covering Location Problem (ACLP). The ACLP belongs to the class of discrete location problems and could be defined in the following way: for a given set of potential facility location sites, a maximally weighted set of facilities is located in such a way that no two placed facilities are inside a pre-specified distance of each other. It is NP hard problem. In this paper we presented the Bee Colony Optimization (BCO) tailored for the ACLP. The BCO algorithm is popular technique inspired by bees' behavior in nature. In the contrary to the previously published papers related to the BCO application on the ACLP, here we focus on weighted version of this location problem. The proposed approach is tested on numerous benchmark problems.

**Keywords:** Anti Covering Location Problem, Bee Colony Optimization, Logistics objects.

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## 1. INTRODUCTION

The Bee Colony Optimization (BCO) is a meta-heuristic which belongs to the class of stochastic swarm optimization methods. The BCO is inspired by the foraging habits of bees in the nature. The basic idea behind the BCO is to create the multi agent system (colony of artificial bees) capable to successfully solve difficult combinatorial optimization problems. The artificial bee colony behaves partially alike, and partially differently from bee colonies in nature. The BCO has been proposed by Lučić and Teodorović [1, 2, 3, 4], and belongs to the class of constructive methods. It was designed as a method which built solutions from the scratch with execution steps, contrary to the local search based meta-heuristics, which perform iterative improvements of the current best solutions. In this paper we present the BCO algorithm tailored to deal with the Anti-Covering Location Problem (ACLP).

The ACLP belongs to an important class of location models which maximizing the total value of facilities sited while also ensuring spatial separation between located facilities. It is discrete location problem and could be defined in the following way:

for a given set of potential facility location sites, a maximally weighted set of facilities is located in such a way that no two placed facilities are inside a pre-specified distance or time standard of each other. In the case of ACLP the total number of facilities to be sited is not given in advance.

If we define a network where the set of facility sites represent the nodes and the arcs represent each pair of nodes which lie within the pre-specified distance or time standard, then the ACLP is equivalent to the Node/Vertex Packing Problem once the network has been defined using the restriction requirement. Node/Vertex Packing Problem and ACLP are closely related to the Maximal Clique and Vertex Cover Problems. Further, they are related to minimum separation and dispersion models [5].

A wide variety of particular applications of the ACLP and related problems can be found in literature. The applications include forest management, nature reserve design, telecommunications equipment sitting, military defense location, undesirable facility location, water conservation, social service provision, zoning policy development, franchise outlet location, cartographic

design, and a range of other planning contexts [7, 8, 9, 10, 11, 12, 13].

The ACLP, as the NP-hard problem [14], was solved by various heuristic and meta-heuristic algorithms: Greedy Heuristic algorithms [9], Lagrangian relaxation [6] and Genetic Algorithm [14]. The BCO implementation on the “unweighted” version of the ACLP (all potential facility sites have the same weights that are equal to one) [13] showed that the BCO is very competitive with other state-of-art techniques. This implementation was illustrated on example of dangerous goods warehouse location problem as an important location problem in the field of hazardous materials logistics. One of directions for future research listed in [13] was to tailor the BCO on “weighted” version of the ACLP. Thus, the purpose of this paper is to present the BCO algorithm tailored to deal with more realistic, “weighted” version of the ACLP and to demonstrate that in this case it can also be successfully applied.

This paper is organized as follows. Section after Introduction provides mathematical formulation of the ACLP. Content of the following Section presents brief description of the BCO and actual implementation of the BCO for solving “weighted” version of the ACLP. Section named Computational examples contains experimental evaluations and the last Section brings conclusions related to the research.

## 2. THE ACLP FORMULATION

The ACLP was introduced by Moon and Chaudhry [8]. There are few mathematical formulations of the ACLP proposed in literature [6, 8].

Let us introduce binary variables  $x_i$  defined in the following way:

$$x_i = \begin{cases} 1 & \text{if node } i \text{ is chosen to be a facility location site} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Consider the following notation:

$i$  – index representing potential location sites,

$n$  – total number of potential location sites,

$w_i$  – node weight (benefit associated with the use of location  $i$ ),

$d_{ij}$  – the shortest distance between node  $i$  and node  $j$ ,

$R$  – pre-specified minimal distance,

$\pi_i = \{j | d_{ij} \leq R \wedge i \neq j\}$  – nodes that are on distance less or equal to  $R$ , excluding particular node  $i$ ,

$M$  – a large positive number.

The following, original, mathematical formulation of the ACLP is proposed by Moon and Chaudhry [8]:

$$\max Z = \sum_i w_i x_i \quad (2)$$

$$Mx_i + \sum_{j \in \pi_i} x_j \leq M, \quad \forall i \quad (3)$$

$$x_i \in \{0, 1\}, \quad \forall i \quad (4)$$

The objective function (2) maximizes the total weighted selection of the facility location sites. Constraints (3) are referred as Neighborhood Adjacency Constraints (NAC). If node  $i$  is selected for facility placement (i.e.  $x_i = 1$ ), then the term  $Mx_i$  equals the right hand side term,  $M$ , and forces  $\sum_{j \in \pi_i} x_j = 0$ . Thus, if a site  $i$  is used, then all sites  $j$  within the  $R$  distance neighborhood of site  $i$ ,  $\pi_i$ , are restricted from use. Constraint (4) defines problem binary variables.

Other mathematical formulations of the ACLP [6] differ from the original ACLP formulation in the specification of the NAC, because of the impact that NAC structure has on problem solvability.

## 3. THE BEE COLONY OPTIMIZATION

The Bee Colony Optimization meta-heuristic was introduced by Lučić and Teodorović [1, 2, 3, 4] as a new direction in the field of Swarm Intelligence.

The BCO algorithm is inspired by the foraging behavior of honeybees. The basic plan behind BCO is to build a multi-agent system (a colony of artificial bees) that can efficiently solve hard combinatorial optimization problems. The artificial bee colony behaves similarly to bee colonies in nature in some ways but differently from them in other ways.

### 3.1 The BCO algorithm

During the evolution of the BCO algorithm authors developed two different approaches. The first approach is based on constructive steps in which bees build solutions step by step. The second approach of the BCO algorithm is based on the improvement of complete solutions in order to obtain the best possible final solution. In this paper we use constructive concept due to the problem nature.

The BCO is a population based algorithm. Population of the *artificial bees* searches for the optimal solution. Every artificial bee generates one solution to the problem. The algorithm consists of two alternating phases: *forward pass* and *backward pass*. During each forward pass, every bee is exploring the search space. It applies a predefined number of moves, which construct and/or improve the solution, yielding to a new solution.

Having obtained new partial solutions, the bees return to the nest and start the second phase, the so-called backward pass. During the backward pass, all bees share information about their solutions. In nature, bees would perform a dancing ritual, which would inform other bees about the amount of food they have found, and the proximity of the patch to the nest. In the search algorithm, the bees announce the quality of the solution, i.e. the value of objective function. During the backward pass, every bee decides with a certain probability whether it will advertise its solution or not. The bees with better solutions have more chances to advertise their solutions. The remaining bees have to decide whether to continue to explore their own solution in the next forward pass, or to start exploring the neighborhood of one of the solutions being advertised. Similarly, this decision is taken with a probability, so that better solutions have higher probability of being chosen for exploration.

The two phases of the search algorithm, forward and backward pass, are performed *iteratively*, until a stopping condition is met. The possible stopping conditions could be, for example, the maximum total number of forward/backward passes, the maximum total number of forward/backward passes without the improvement of the objective function, etc.

The BCO algorithm parameters whose values need to be set prior the algorithm execution are as follows:

$B$  - the number of bees involved in the search and

$NC$  - the number of constructive / improvement moves.

The pseudo-code of the BCO algorithm could be described in the following way:

*Do*

1. Initialization:  $a(n)$  (empty) solution is assigned to each bee.

2. For ( $i = 0$ ;  $i < NC$ ;  $i++$ )

**//forward pass**

(a) For ( $b = 0$ ;  $b < B$ ;  $b++$ )

i) Evaluate possible moves.

ii) Choose one move using the roulette wheel.

**//backward pass**

(b) For ( $b = 0$ ;  $b < B$ ;  $b++$ )

Evaluate the partial/complete solution for bee  $b$ ;

(c) For ( $b = 0$ ;  $b < B$ ;  $b++$ )

Loyalty decision using the roulette wheel for bee  $b$ ;

(d) For ( $b = 0$ ;  $b < B$ ;  $b++$ )

If ( $b$  is uncommitted), choose a recruiter by the roulette wheel.

3. Evaluate all solutions and find the best one.

*while* stopping criteria is not satisfied.

Steps 1, 2(a) and 2(b) are problem dependent and should be resolved in each BCO implementation. On the other hand, there are formulae specifying steps 2(c), loyalty decision, and 2(d), recruiting process, and they are all described in the next section in details.

#### 4. THE BCO APPROACH TO THE ACLP

In this section, we describe our implementation of the BCO algorithm to be applied to the weighted version of Anti Covering Location Problem. In order to make it more interesting to logistics engineering audience, we choose to illustrate it on example of dangerous goods warehouse (in following text warehouse) location problem. Those facilities (for example: radioactive waste warehouses, explosives warehouses, as well as noise, odor or heat emitters, etc.) generate different undesirable effects that can be felt within certain geographical area. Making decisions about their spatial positions are crucial when it comes to minimize the environmental risk. Such facilities should be located under condition of the minimal safety distance. For some dangerous goods (for example some explosives) the minimal safety distance may be determined as constant value which depends only on the dangerous goods' characteristics. Weights which represent the warehouse capacities are associated to potential locations.

The objective is to maximize quantity of dangerous goods stored respecting the minimal safety distance between warehouse facilities.

The main specificity of BCO application to the ACLP is in the fact that  $NC$  has to be equal to one, and number of located warehouses isn't known in advance.

Let us denote by  $V_i$  bee's utility when choosing the node  $i$  to be a warehouse site (within a single forward step, each bee has to select  $NC=1$  node). However, in this paper, it is assumed that there are two bee utility criteria, i.e.  $V_{1i}$  and  $V_{2i}$ , in order to better describe the nature of the weighted ACLP. In this sense, the first utility criterion is:

$$V_{1i} = \frac{N^{max} - N_i}{N^{max} - N^{min}}, \quad i = 1, 2, \dots, n \quad (5)$$

where:

$N^{max} = \max_i \left( w_i + \sum_{j \in \pi(i)} w_j \right)$  - the largest possible sum of nodes' weights which are jeopardized by any observed location in current forward pass;

$$N^{min} = \min_i \left( w_i + \sum_{j \in \pi(i)} w_j \right) - \text{the smallest possible}$$

sum of nodes' weights which are jeopardized by any observed location in current forward pass;

$$N_i = w_i + \sum_{j \in \pi(i)} w_j - \text{the sum of nodes' weights}$$

which are jeopardized by the  $i$ -th observed location in current forward pass.

The second utility criterion is:

$$V_{2i} = \frac{w_i}{N_i}, \quad i = 1, \dots, n \quad (6)$$

We set up  $p_i$  (the probability that specific bee chooses node  $i$ ) to:

$$p_i = \frac{T_i}{\sum_{k=1}^K T_k}, \quad i = 1, \dots, n \quad (7)$$

where:

$T_i$  - the relative closeness to the ideal solution for node  $i$  calculated with TOPSIS method [16] and with the following (empirically obtained) criteria weights: 0.75 for  $V_{1i}$  and 0.25 for  $V_{2i}$ .

$K$  - the number of "free" nodes (not previously chosen).

Using relation (7) and a random number generator, we determine the nodes to be chosen by each bee.

After determining warehouse locations in current partial solution, it is necessary to evaluate all bees' solutions. It is obviously that particular partial solution is better if the sum of located nodes' weights is higher and vice versa.

Let us denote by  $C_i$  ( $i=1,2,\dots,b$ ) sum of nodes' weights in the solution generated by the  $i$ -th bee. Let us normalize the value  $C_i$ . We denote by  $O_i$  normalized value of  $C_i$ , i.e.:

$$O_i = \frac{C_i - C_{max}}{C_{max} - C_{min}}, \quad O_i \in [0,1], \quad i = \overline{1,b} \quad (8)$$

where  $C_{min}$  and  $C_{max}$  are the minimal and the maximal sum of nodes' weights obtained by all bees, respectively.

After the completion of a forward pass, each bee decides whether it stays loyal to the previously discovered partial solution or not. This decision depends on the quality of its own solution related to all other existing solutions. The probability that  $b$ -th bee (at the beginning of the new forward pass) is loyal to its previously generated partial solution is expressed as follows:

$$p_b^{u+1} = e^{-\frac{O_{max} - O_b}{u}}, \quad b = 1, \dots, B \quad (9)$$

where:

$O_b$  - denotes the normalized value for the objective function of partial solution created by the  $b$ -th bee;

$O_{max}$  - represents the maximum over all normalized values of partial solutions to be compared;

$u$  - counter of the forward passes (taking values 1, 2, ...,  $NC$ ).

For each uncommitted bee it is decided which recruiter it will follow, taking into account the quality of all advertised solutions. The probability that  $b$ 's partial solution would be chosen by any uncommitted bee equals:

$$p_b = \frac{O_b}{\sum_{k=1}^R O_k}, \quad b = 1, \dots, R \quad (10)$$

where  $O_k$  represents the normalized value for the objective function of the  $k$ -th advertised solution and  $R$  denotes the number of recruiters. Using equation (10) and a random number generator, each uncommitted follower joins one recruiter through a roulette wheel.

## 5. COMPUTATIONAL EXAMPLES

Computational results for the BCO algorithm are presented in this section. All analyzed problem instances are generated by the authors of this paper and they are available upon request. The obtained results are presented in the Table 1. All the tests were performed using SciLab (version 4.0) on Intel Core i7 i7-4820K computer processor with 3.7 GHz and 4 GB of RAM.

The proposed BCO algorithm was capable to find the optimal solution for all analyzed problem instances. The CPU times for all problem instances varied from 0.01 to 0.101 second. Additionally, we solved all tested examples by LpSolve in order to compare the minimum BCO CPU times needed to obtain the solutions with ones which were reported by LpSolve. LpSolve was capable to find the optimal solution for all analyzed problem instances and its CPU times varied in [0.1, 0.5] seconds interval. Therefore, presented numerical results showed that the BCO generated successful performances. These performances will become more important for a larger size networks.

**Table 1. Results for the generic data set (20 nodes)**

$R^a$	$D^b$	$O^c$	$BCO^d$	$I^e$	$CPU^f$	$BCO_m^g$	$I_m^h$	$CPU_m^i$
50	0.076	6840	6840	1	0.001	6840	7.9	0.004
100	0.126	6840	6840	416	0.125	6840	2403.0	0.707
150	0.168	6789	6789	8	0.003	6789	63.7	0.021
200	0.210	5525	5525	40	0.010	5525	8006.2	1.917
250	0.260	5332	5332	1861	0.041	5332	17698.3	3.865
300	0.326	5068	5068	138	0.046	5068	7932.9	1.587
350	0.376	4855	4855	200	0.038	4855	1759.9	0.327
400	0.421	4855	4855	181	0.034	4855	3396.9	0.591
450	0.492	4298	4298	13	0.002	4298	5096.8	0.841
500	0.545	4298	4298	1.5	0.101	4298	10576.1	1.617
550	0.608	3543	3543	55	0.010	3543	19314.6	2.725
600	0.647	3084	3084	1	0.001	3084	31.1	0.006
650	0.690	2463	2463	1	0.002	2463	53.3	0.010
700	0.732	2316	2316	1	0.001	2316	26.8	0.007
750	0.774	1798	1798	8	0.002	1798	37.0	0.007
800	0.832	1798	1798	1	0.001	1798	20.1	0.005
850	0.868	1702	1702	4	0.001	1702	17.2	0.005
900	0.90	1702	1702	1	0.001	1702	14.6	0.005
950	0.953	1576	1576	1	0.001	1576	15.4	0.002
1000	1.0	859	859	1	0.001	859	7.6	0.002

<sup>a</sup> Pre-specified minimum distance.

<sup>b</sup> Network density.

<sup>c</sup> Optimal objective function value.

<sup>d</sup> The best objective function value obtained by BCO using two artificial bees .

<sup>e</sup> The minimum number of iterations (among optimal solutions discovered) during ten problem solving cycles.

<sup>f</sup> The minimum CPU time in seconds (among optimal solutions discovered) during ten problem solving cycles.

<sup>g</sup> The mean objective function value obtained by BCO using two artificial bees during ten problem solving cycles.

<sup>h</sup> The mean number of iterations during ten problem solving cycles.

<sup>i</sup> The mean CPU time in seconds during ten problem solving cycles.

## 6. CONCLUSION

The Bee Colony Optimization (BCO) meta-heuristic is used as a tool to solve weighted version of the Anti-Covering Location Problem (ACLP). This paper represents a natural extension of our previous study [13], in which ‘unweighted’ ACLP was solved.

For the first time in relevant literature we considered the multi-objective approach in order to determine utilities that bees have when locate a facility at a given node. We stated from the assumption that decisions related to the utility of facility/warehouse locations should be made in

the presence of trade-offs between two conflicting criteria. We merged these criteria using TOPSIS method.

The BCO algorithm was tested on a variety of numerical examples. The performed numerical experiments show that the proposed algorithm can generate high-quality solutions in a reasonable CPU times.

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# INTRODUCTION TO AUTOSTOW(#) FUNCTION IN DPW TERMINALS AS PART OF STANDARDISATION AND OPTIMISATION OF VESSEL AND TERMINAL OPERATIONS

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**Abstract:** *The paper summarises DP World's experience in optimisation of container terminal waterside operations using NAVIS Vessel AutoStow function. AutoStow function, as demonstrated by DP World in Australia, provides more efficient ship planning and container terminal operation; standard level of service with reduced cost. The ship planning function in DP World in Australia is based on implementation of vessel working and terminal yard strategies to defined plans, where overall terminal strategy might be compromised because of manual input and control. Introduction of automated ship planning function allows DP World Australia's ship planning team to optimise customer and terminal needs ensuring most effective terminal operations with minimum cost.*

**Keywords:** *optimisation, container terminal, ship planning.*

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## 1. INTRODUCTION

Container ship travel on “round-robin” routes where at each port of destination (POD) containers may be unloaded and additional containers destined for subsequent ports may be loaded. Determining a viable arrangement of containers that facilitates this process, in cost effective way, makes up the container stowage problem [1]. Stowage planning is the core of ship planning [2]. Stowage plan defines positions for all containers on boards of a ship, accordingly to the orders of ports in a ship rotation. Usually stowage planning does not act with specific containers identified by numbers, but on categories of containers. Constraints to be satisfied mainly result from the stability of the ship [2].

In former times, stowage plans were created by the captain of the ship, but nowadays the creation of stowage plans is a two-step process. Firstly, a rough stowage plan is created by the shipping line that considers stowage positions on the vessel. Secondly, based on the rough stowage plan of the shipping line, the ship planners of the container terminal create a more precise stowage plan with specific containers [3].

Stowage planning in real terminal operation is either a manual or optimization process based on software application. Because the stowage plan is generated before the beginning of ship loading, optimization concept is offline. Stowage

optimization concept has been implemented in numerous software applications. Some of examples are *SimpleStow* flagship program designed specifically for stowage planning of container vessels and container data processing, developed by AMT Marine software Inc. [4]; Autoship Systems Corporation Stowage Planning Systems which includes hydrostatics analysis engine – *Autoload* [5]; Navis VESSEL AUTOSTOW application module that automatically generates stow plans for the entire ship or by specific bay based on rules set by the planner combining vessel stowage factors with yard constraints and operational parameters [6].

The current ship planning function in DP World Australia (DPW) container terminals was based on implementation of vessel working and yards strategies to defined plans, where overall terminal strategy might be compromised because of manual input and control. Ship planning relay on individual skills and planner's ability to optimise customer and terminals needs ensuring service is delivered in most effective way with minimum cost to terminal. The current planning process is tentative and doesn't allow terminal management to assess several plans (options) based on different strategies in short period of time. Furthermore the current planning process is relatively slow to respond to unplanned disruptions in vessel operations.

Therefore, ship planning needs to move towards dynamic planning in order to ensure optimum results

for dynamic terminal operations and that terminal strategies are followed at all times.

As a solution, DP World National Planning Centre (NPC) is implementing AutoStow in DPW terminals as part of optimisation of vessel operations. Hence, introducing the planning process based on the AutoStow software application module is the main objective of this paper.

The remaining of the paper is organized as follows. Section 2 presents AutoStow application module, while section 3 describes planning process based on this software tool. Some concluding remarks are given in section 4.

## 2. AUTOSTOW APPLICATION MODULE FOR STOWAGE PLANNING

AutoStow is an advanced application module that plans ships to distribute work among terminal Automated Stacking Cranes / RTG / straddles in operations including vessel, rail, and yard points of work.

Preparation for AutoStow function required full assessment of:

- Vessels
- Cargo Configuration
- AutoStow Factor Filters
- Operational Strategies
- Yard Allocations

Our main goal with AutoStow function is to minimize the crane delay and to select the optimum container from yard that matches projection with optimum utilisation of yard equipment and terminal resources.

### 2.1 Vessels

Vessel profile files have been updated with necessary data in relation to Stack Weights and Stack Heights (Figure 1.). The biggest challenge was to determinate permissible stack weights based on vessel dynamic stability. In consultation with vessel operators standard vessel sailing condition on departure each port were assessed and standard (predefined) GM<sup>1</sup> was established (Figure 2.). That allowed us to determine one sailing condition on departure and set permissible stack weight for that condition only.

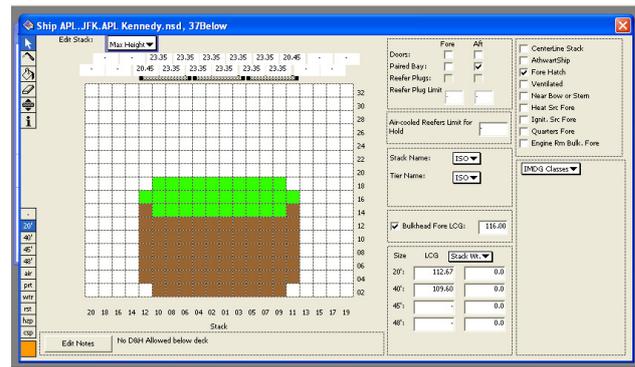


Figure 1. Vessel Profile File: Stack Heights

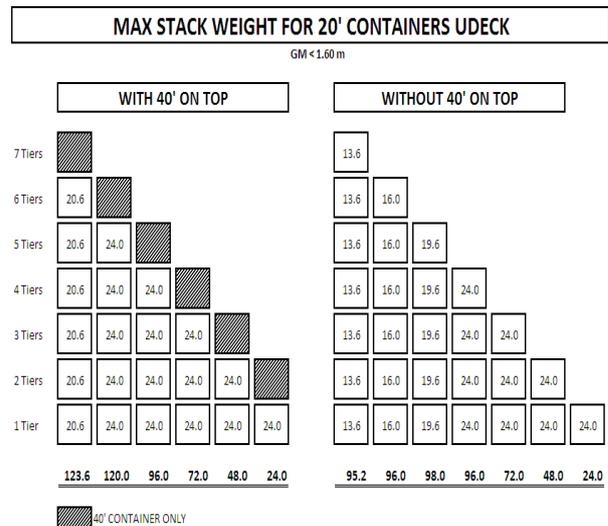


Figure 2. ANL Windarra: Permissible Stack Weights for 20' Containers for GM < 1.6m

### 2.2 Cargo Configuration

Cargo configuration is very important factor for ship and yard planning as vessel slots and stows are allocated based on cargo configuration. In our analysis we were looking for the model ship, core cargo, trends and season oscillations by Trade (Service). Extra heavy containers are dominant out of Australia and keeping vessels' stack weights within limits is planners' biggest challenge. Vessels ex Australia usually hits their DWT allocation before TEU allocation. In some trades more than 75% of 20' are heavier than 24t, which is max weight per 20' slot on most ships (see Figure 3.). Yard allocations were adjusted to allow optimum container selectivity in cases where majority of 20' are heavier than vessel slot: extra heavy containers (>24t) are grouped (one allocation) and light containers (<15t) were spread in several weight groups (allocations). This allows better access to light containers to match permissible stack weight (refer to Figure 2.).

<sup>1</sup> GM denotes "metacentric height of a vessel". For a vessel to be stable the numerical value of GM must be positive. The available GM must always be larger than the required GMs. The requirements vary considerably for different types and sizes of vessels.

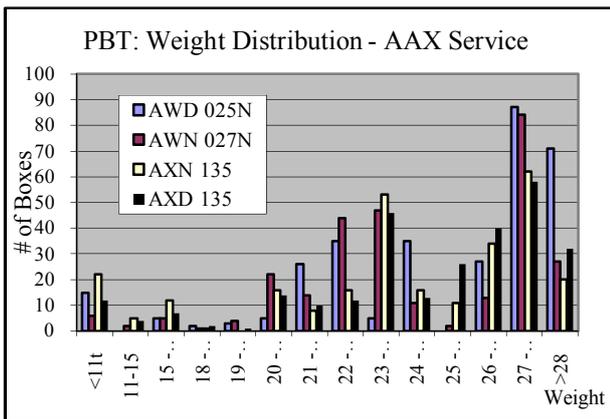


Figure 3. Weight Distribution – 20’ Dry AAX Service ex SYD

2.3 AutoStow factor Filter

AutoStow filters have been created based on vessel operator’s stow requirements. The Stow factor must be in synchronisation with the Yard Strategy and Expert Decking which then ensure that AutoStow will select containers correctly. Projections are created in accordance to the AutoStow factors Filters defined as per below Figure 4.

Figure 4. Stow Factor Filters

2.4 Operational Strategies

An AutoStow strategy is made up of a standard set of AutoStow parameters which are actually numerical decision factors that are accumulated and weighted against each other to determine the best stowage outcome for a container. This way, the system assigns the lowest scoring matching container to a vessel slot.

Terminal operational strategies have been defined as well as triggering points where the terminal will switch on to new strategy (eg: resources available, cargo configuration, volume, etc).

Auto Stow strategies are split into three parts (Figure 5.):

- Configuration – Settings related to the terminal Equipment and operational philosophy and operational needs
- Options – Settings related to container conditions that might be included or allowed

in the AutoStow calculation process, it determines how system shall handle the optional container conditions

- Penalties – settings (penalties) that allows calculation and evaluation of the best candidate. With penalties user controls the behavior of AutoStow by weighting the variables with penalty points

Figure 5. AutoStow Strategy – RTG Terminal Sydney

In RTG Terminals strategies are to be created by Crange and resources available, for straddle and ASC terminals CONFIG Settings are simple and they have only one strategy.

Penalty values balance inevitable trade-offs between competing yard and vessel efficiencies, and customize strategies that reflect operational objectives. By setting parameter values, we configure the strategy the system uses to avoid problems such as rehandles, weight inversions, and CHE clashes in the yard. The best strategy depends largely on the type of CHE, but also on particular terminal’s practices.

AutoStow chooses the best container to load by evaluating each candidate. The control of the behavior of AutoStow is by weighting the variables with penalty points. The higher the penalty, the less chance that action will occur.

AutoStow assign container to particular Point Of Work (POW) based on set parameters that take into consideration in real time:

- Estimated time of move
- Crane productivity / rate
- ASC / RTG productivity
- Current position of ASC / RTG
- Number of rehandles (defined by flow pattern)
- Permissible stack weight
- Multiple point load in twin lift option
- Late receipts etc

The projections for all POWs will be sorted based on move time, so they will be intermingled, and AutoStow will plan them in that order.



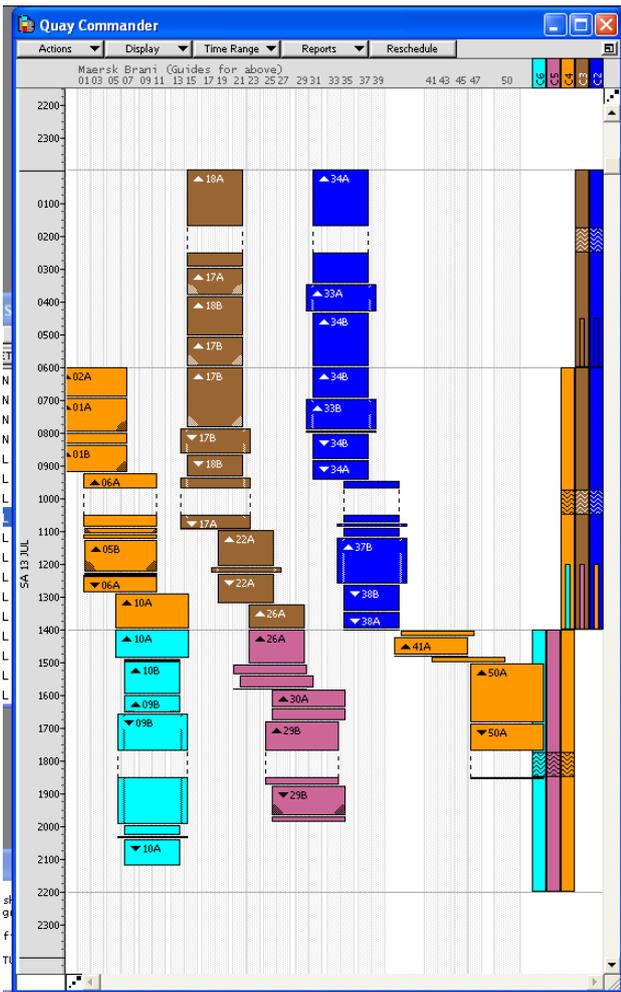


Figure 9. Quay Commander

After running the AutoStow load plan and results are analysed (Figure 10.) and minor adjustments are to be made if planner is not fully satisfied. For example planner have to check yard clashes by Move Hour versus Points of Work (Figure 11.)

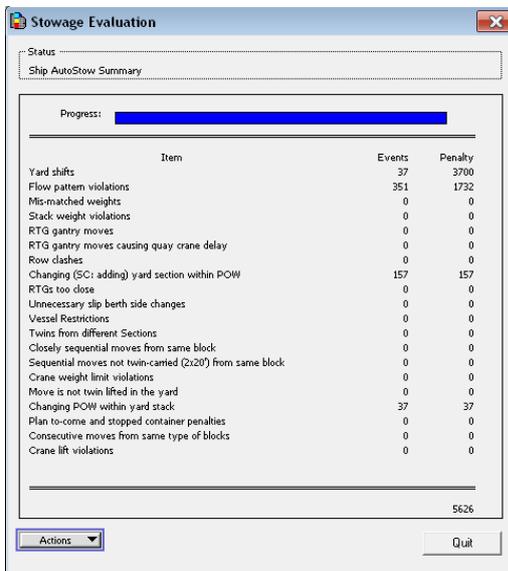


Figure 10. AutoStow Stowage Evaluation

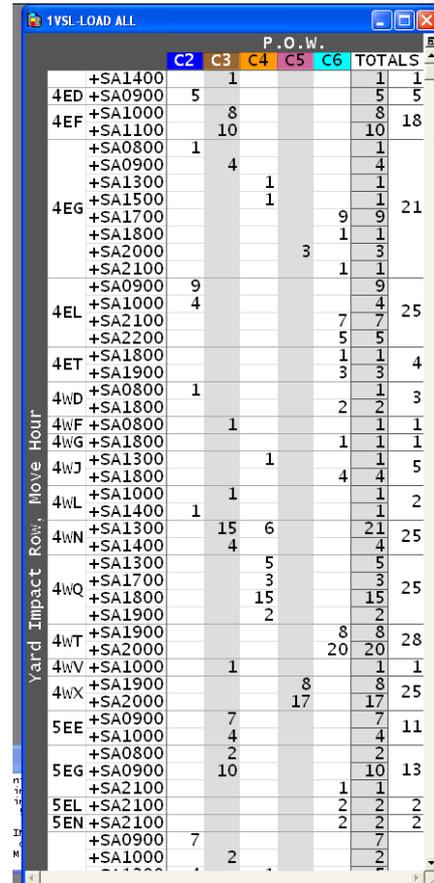


Figure 11. Yard Impact Row and Move Hour by Point of Work

A feedback and report of any anomalies is important for further adjustments of yard allocations (Figure 12.), penalties, weight groups etc. Operational team is regularly assessing: AutoStow algorithm used and parameters related to Weight management, Container Handling Equipment (CHE) deployment and Yard Flow management for fine tuning of related penalties and settings.

AutoStow require correct preplan and projections. Time spent on preplan will increase where time on sequencing will be reduced. AutoStow will increase consistency and accuracy of our product by focusing on projections rather than actual container and by eliminating simple planning errors, it will also allow planner to promptly respond on any replanning requirements.

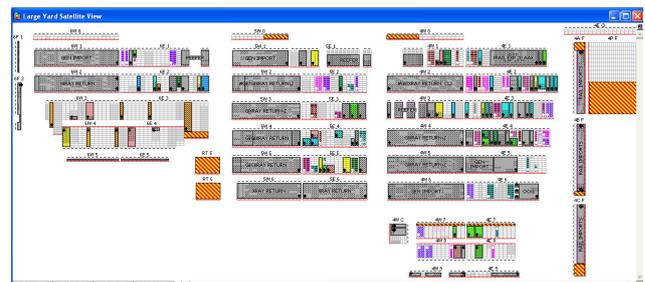
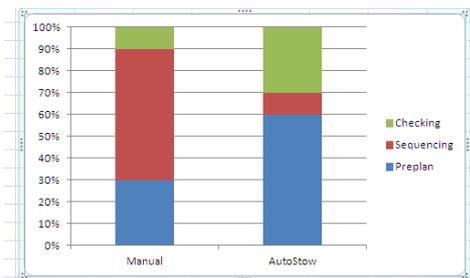


Figure 12. PBT Yard Allocation

AutoStow require more time to be spent on pre-plan but actual time on sequencing containers from yard will be reduced (Figure 13.). Overall planners will have more time available for checking and ensuring optimum terminal operations are met at all times. On long term actual savings are coming from reduced time required for checking as AutoStow strategies are developed and finetuned; and prompt respond on any replanning requirements during vessel operations. AutoStow will also increase consistency and accuracy of our product by focusing on projections rather than actual container and by eliminating simple planning errors.



**Figure 13. Time required for Manual v Auto Stow ship planning**

#### 4. CONCLUSION

Ship planning function, as part of terminal operations, is based on implementation of vessel working and yard strategies to defined plans, where overall terminal strategy might be compromised because of manual input and control. The ship planning relay on individual planner's skills; it is tentative process and it doesn't allow assessment of several plans (options) in short period of time. This process is relatively slow to respond to dynamic terminal operations and unplanned disruptions of vessel operations.

Automatisation of ship planning process using NAVIS Vessel AutoStow allows dynamic planning that ensures optimum results for dynamic terminal operations. It also ensures that terminal strategies are followed at all times.

Successful implementation of AutoStow function require full assessment of vessels and cargo configurations (external factors) and terminal operational strategies (internal factors) which must be clearly defined.

Automated ship planning using AutoStow increases consistency and accuracy of ship planning product, standardisation of waterside terminal operations and it increases planner's ability to quickly respond on any changes and any replanning requirements.

Following implementation of AutoStow in DP World Melbourne terminal overall ship planning time has been reduced by 1 to 1.5 hrs for the vessels with exchanges of up to 2000 containers.

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## CITY LOGISTICS CONCEPTS OF BELGRADE

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**Abstract:** This paper presents a procedure for evaluating city logistics concepts of Belgrade. Concepts are defined in accordance with the current urban plans, the present state of the city's logistics system, development plans and worldwide experiences in this field. In the process of concepts evaluation, the goals of different stakeholders (residents, senders and receivers, logistics service providers, city government) are analyzed. These goals are often conflicting and generate a large number of criteria that need to be included in the city logistics concept selection process. Because of the linguistic assessment of a large number of criteria a fuzzy "analytical hierarchy process" (FAHP), as a fuzzy extension of conventional multi-criteria decision-making method (MCDM), is used for selecting the city logistics concept of Belgrade.

**Keywords:** city logistics, conceptions, evaluation, multi-criteria decision-making.

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### 1. INTRODUCTION

City is the place of largest concentration of economic and social activities, and logistics is very important for the sustainability and the economy of the city. In order to make deliveries more efficient, to preserve the environment and to increase the attractiveness of the city, various initiatives are defining and different conceptual solutions are applying. However, changes are slow, and main problem is the lack of planning activities and comprehensive and long-term city logistics policy.

While defining concepts of city logistics (CL), it is necessary to consider the goals and interests of all stakeholders (shippers, receivers, carriers, logistics service providers, residents, city government) [1]. They all want an attractive city by all criteria, but individual goals are often in conflict, and the introduction of changes, which are positive in terms of one group, can cause a number of adverse effects for the others. This problem is solved by defining a large number of criteria to take into account all requirements and interests of stakeholders [2].

The procedure of selecting the CL concept of Belgrade is presented in this paper. All the described concepts have certain advantages and disadvantages in terms of the evaluation criteria, so FAHP as a fuzzy extension of conventional AHP method of

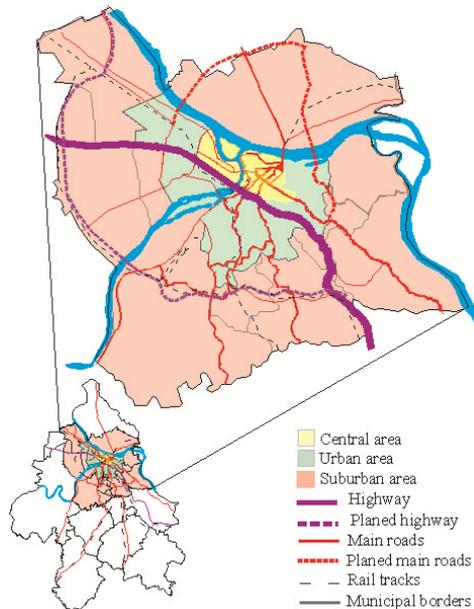
MCDM is used for selecting the CL concept of Belgrade.

### 2. DEFINING THE PROBLEM

Belgrade, with a territory of over 320,000 ha and more than 2 million people, is a metropolitan area with complex freight and transport flows. Administrative Belgrade has 17 municipalities, i.e. the City of Belgrade (about 25% of the total territory) and eight suburban municipalities. In this paper are presented the CL concepts for the city of Belgrade which, by the economic, structural, transportation, physical, regulatory, and other characteristics can be divided into three areas: the central area (with the historical core), urban and suburban area (Figure 1).

The biggest logistical problems are present in the central city area. This area occupies about 11% of the city, it is home to 40% of the population and it contains almost 60% of the jobs. The area is characterized by a large number of small and frequent deliveries because 50% of the generators are small stores of trade, service and catering activities [3]. The port and rail intermodal terminal, which are serving the long haul flows and generate the entry of heavy freight vehicles, are situated in this area. On the other hand, many firms developed warehousing and distribution activities on the high-valuable land of the central area. The existing

logistics systems initiate movement of a large number of freight vehicles and in many cases perform the function of logistics for users who are not situated in the city area.



**Figure 1. Areas and major traffic routes of Belgrade**

The Belgrade administration does not have a service that deals with the problems and plans of city logistics. There are no monitoring parameters, research and analysis, and no systematic approach for solving the problems of city logistics. Of all city logistics initiatives, only those of regulatory character are present, and constraints are defined, adopted and applied without any analysis of conditions and influences. Unlike Belgrade and Serbia, in the European Union city logistics, primarily urban freight transport, is the subject of local, regional and national policies in the areas of transport planning, environment and economy. These policies, in addition to legislation, regulations and licensing on different grounds, are mainly promoting and encouraging the consolidation of cargo flows through the voluntary cooperation of companies in the field of logistics in combination with the development of logistics centers. Major European and national projects are carried out with the goal of obtaining relevant data and overview of the situation, and in order to make logistics operations more efficient, many initiatives are undertaken, particularly in terms of impact on the environment and quality of service.

The aim of this study was to analyze the potential CL concepts of Belgrade and to select the best one for a wider set of different goals and interests.

### 3. CITY LOGISTICS CONCEPTS

Existing problems of logistics, worldwide experiences, demands for changing the urban plans, primarily of the central city area, ownership changes of economic systems and their business vision, place and role of Belgrade in the regional logistics, significantly affected the definition of four CL concepts:

- CL1*: Decentralized, satellite system with the dominant role of road transport.
- CL2*: Centralized-decentralized system with the application of cargo trams.
- CL3*: The network core with the application of cargo trams and electric vehicles.
- CL4*: The network system with intermodal transport.

**The CL1 concept** involves decentralized storage of goods on the edge of the city with a certain concentration of logistics systems in the planned freight village (FV) in Batajnica and city logistics terminal (CLT) at the site of Ada Huja. Given the dominant role of road transport, for supplying the central area, satellite terminals with cross-docking function would be developed along the access roads. The purpose of these terminals is the transshipment from bigger to small delivery vehicles and flows consolidation for the supply of urban areas. In order to shorten delivery vehicles dwell time in front of the stores, the use of roll pallets is recommended. The function of a CLT would be storage and distribution of goods using eco-vehicles for the part of generators in central area. In addition, the CLT would provide services of reverse logistics and home delivery. The concept also support development of small city terminals intended for a specific group of generators, such as restaurants or specific sites (larger construction sites). The aim is the consolidated delivery and fewer vehicles in the function of supplying.

**The CL2 concept** involves the development of multiple CLTs on the outskirts of the central city area. These centers would, besides warehousing and consolidated deliveries, also develop various VAL (Value Added Logistics) services, reverse logistics services, home deliveries, deliveries to specific assumption zones (pickup points), etc. Delivery of goods from distant locations, from FV in Batajnica or warehouses on the outskirts of town, to the nearest CLT would be realized by road transport, and cargo tram would circulate between the CLTs. Goods distribution from the CLT to the generators in the influence area would be realized by applying small delivery vehicles and eco-vehicles.

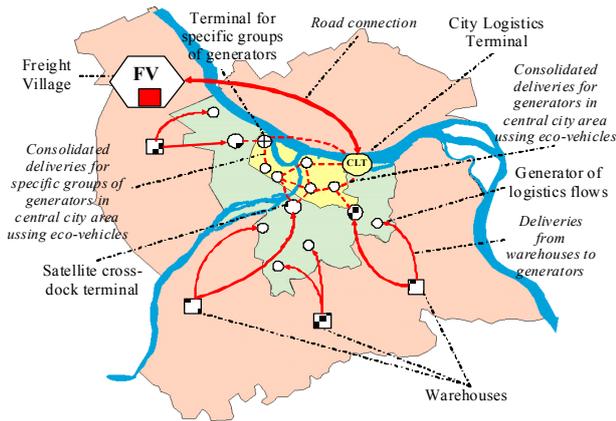


Figure 2. The CL1 concept

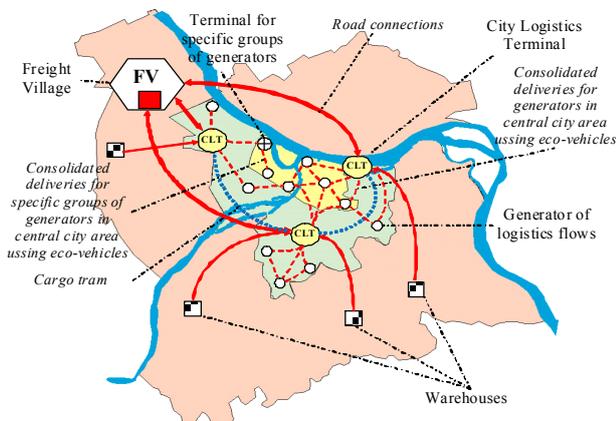


Figure 3. The CL2 concept

*The CL3 concept* is an inception of complex city logistics network with two FVs on the outskirts of the city and four CLTs on the edge of the central city area. The purpose of the FV is stopping of distant road flows, and of the CLT consolidated delivery of goods in the city. This concept involves the use of rail transport between FVs and cargo trams between FVs and related CLTs. Cargo tram system would also be developed within the central city area, but in a function of the supply, i.e. the delivery to special zones for goods assumptions, and reverse logistics. Between the cargo tram station and generators, flows would be realized with pedestrian traffic and with the use of roll pallets as transport units. In this way, the share of road freight transport in the central city area, but also in the entire city, is reducing.

*The CL4 concept* is focused on the development and implementation of intermodal transport in the function of city logistics. It involves the formation of a network of logistics centers of different categories and more significant participation of railways in the realization of flows. At the site of Ada Huja, a CLT for consolidated delivery for the generators in the gravity area, as well as intermodal transport terminal, would be developed. These two systems would have the possibility for rail connection with

intermodal terminals in other locations, i.e. FVs on the outskirts of the city, with the use of shuttle trains. Part of the railway infrastructure passing through the central city area, would be retained, but with the aim of increasing the role of railways in connecting urban areas. From the site of Ada Huja, flows between CLTs would be realized through a circular cargo tram line. Distribution of goods within the CLT zone would be realized with the application of small delivery eco-vehicles.

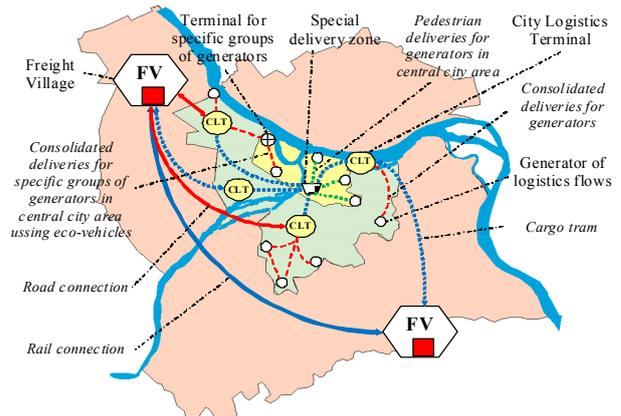


Figure 4. The CL3 concept

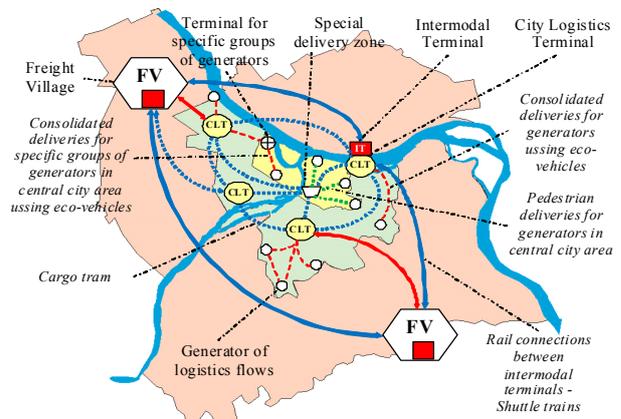


Figure 5. The CL4 concept

Each concept has certain advantages and disadvantages, and each requires the support of local authorities in the planning and implementation, primarily through the definition of development plans and regulatory measures.

#### 4. CONCEPTS EVALUATION CRITERIA

Described concepts can be distinguished in terms of numerous criteria. In this paper, for their evaluation and ranking, the criteria described below are used.

*CI - Investments for the concept development.* Considering the least changes from the current situation, the CL1 concept requires the least investment. Investments for development of other

concepts are significantly higher and depend on the micro-location, size and structure of the planned infrastructure.

**C2 - Possibility of implementation.** Described concepts differ in terms of time, speed and complexity of implementation and understanding by all stakeholders. Complex systems require a large number of researches, projects, discussions, legislation adaptation, education and training, i.e. a series of actions and measures to support the establishment of the system.

**C3 - Quality of logistics service.** Concepts that involve a higher level of cooperation and coordination, with the use of modern technology and a wider range of services, significantly improve the quality parameters of logistics service (accuracy, reliability, flexibility).

**C4 - Goods delivery costs.** Direction and consolidation of flows in logistics centers, city terminals, stimulates the redistribution of modal transport work and enables better use of road vehicles' cargo space which reduces the number of vehicles and traveled kilometers, and thus the delivery costs.

**C5 - Redistribution of modal transport work.** The development of logistics systems and the offer of a variety of services create a significant potential to attract cargo flows, and flow consolidation justifies the significant use of alternative transportation forms in the goods distribution. With the development of intermodal terminal next to the central city area, in the function of city logistics, concept CL4 have the advantage by this criterion.

**C6 - Aspect of ecology.** By eliminating long haul road flows and by applying the concept of consolidation and, in terms of ecology, acceptable transport systems and technologies, the total number of road freight vehicles, and thus the negative environmental impacts and energy consumption is significantly reducing.

**C7 - Aspect of safety.** By reducing the volume of traffic and congestion on city roads, the number of conflicts is also reducing. As it only relies on road transport, the CL1 concept is worse than the other by this criterion.

**C8 - Land use.** Synergy effects, in terms of capacities needed, is achieving by developing logistics systems for multiple users. Sharing leads to reduction of storage and transportation systems and equipment, for the same flow volumes. On the other hand, the development of city terminals reduces the need for expensive storage spaces in the stores of the central city area. The space for the development of core business or some attractive content is freeing in this way.

**C9 - The degree of the commodity flow transformation.** Each stop of the commodity flow and its transformation in the terminals, logistics centers, increase the complexity, costs and time of logistics chains realization. The application of the CL4 concept requires the highest degree of cooperation and consolidation, i.e. it is the most complex realization of the chain.

**C10 - Impact on the attractiveness and development of the city.** With the construction of an efficient logistics network entire region becomes a magnet for attracting flows and investments for development of all economic sectors. On the other hand, service users, especially small and medium-sized enterprises, are relieved of the investment and the risk of developing logistics systems; they are getting better logistics service at a lower cost and the opportunity to concentrate on the development of the core business. Also, electric vehicle distribution systems and cargo trams fit into the modern architectural structures and increase the attractiveness of the city.

## 5. EVALUATION OF CITY LOGISTICS CONCEPTS OF BELGRADE

Application of the fuzzy set theory enables decision makers to include immeasurable, incomplete, inaccessible and partially unknown information into a decision model. In this paper fuzzy AHP was used to select the CL concept of Belgrade.

Although conventional AHP [4], beside quantitative, also takes into account qualitative criteria, it is not able to depict the ambiguity and vagueness of decision makers thinking. Therefore, to solve the hierarchical fuzzy problems a fuzzy AHP method has been developed as a fuzzy extension of AHP method [5]. The first step of the method application is formation of the hierarchical structure of the problem to be solved. The hierarchy has at least three levels, the ultimate goal at the top, a number of criteria and the alternatives at the bottom. For the problem set like this, analysis is performed to determine the relative weights of the criteria at each hierarchy level and the value of alternatives, concepts, in relation to the criteria. The analysis includes a comparison of all pairs of criteria and comparison of all pairs of concepts, in relation to the criteria. The linguistic scale that can be converted into triangular fuzzy numbers, shown in Table 1, is used for comparison.

**Table 1. Fuzzy scale for criteria/concepts comparison**

Linguistic expressions	Fuzzy numbers
Absolutely preferable/better (AP/B)	(8, 9, 10)
Very preferable/better (VP/B)	(6, 7, 8)
Quite preferable/better (QP/B)	(4, 5, 6)
Moderately preferable/better (MP/B)	(2, 3, 4)
Equally important/good (EI/G)	(1, 1, 2)

Different procedures have been developed to solve FAHP, and in this paper is used a logarithmic fuzzy preference programming (LFPP) method [6] which is an extension of a fuzzy preference programming (FPP) method [7]. FPP method starts with forming a fuzzy comparison matrix ( $\tilde{A}$ ) elements of which are triangular fuzzy judgments  $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$  of comparing element  $i$  in relation to element  $j$ . LFPP method take logarithm values of fuzzy judgment  $\tilde{a}_{ij}$  from matrix  $\tilde{A}$  by the following approximate equation:

$$\ln \tilde{a}_{ij} \approx (\ln l_{ij}, \ln m_{ij}, \ln u_{ij}), \quad i, j = 1, 2, \dots, n \quad (1)$$

That is, the logarithm of a triangular fuzzy judgment  $\tilde{a}_{ij}$  can still be seen as an approximate triangular fuzzy number, whose membership function can be defined as:

$$\mu_{ij} \left( \ln \left( \frac{w_i}{w_j} \right) \right) = \begin{cases} \frac{\ln(w_i/w_j) - \ln l_{ij}}{\ln m_{ij} - \ln l_{ij}}, & \ln \left( \frac{w_i}{w_j} \right) \leq \ln m_{ij}, \\ \frac{\ln u_{ij} - \ln(w_i/w_j)}{\ln u_{ij} - \ln m_{ij}}, & \ln \left( \frac{w_i}{w_j} \right) \geq \ln m_{ij}, \end{cases} \quad (2)$$

where  $\mu_{ij}(\ln(w_i/w_j))$  is the membership degree of  $\ln(w_i/w_j)$  belonging to the approximate triangular fuzzy judgment  $\ln \tilde{a}_{ij} = (\ln l_{ij}, \ln m_{ij}, \ln u_{ij})$ , and  $w_i$  are crisp values of the priority vector  $W = (w_1, \dots, w_n)^T > 0, \sum_{i=1}^n w_i = 1$ .

It is necessary to find a crisp priority vector to maximize the minimum membership degree:

$$\lambda = \min \{ \mu_{ij}(\ln(w_i/w_j)) \mid i = 1, \dots, n-1; j = i+1, \dots, n \}.$$

The resultant model can be constructed as:

$$\begin{aligned} & \text{Max } \lambda \\ & \text{s.t. } \begin{cases} \mu_{ij}(\ln(w_i/w_j)) \geq \lambda, i = 1, \dots, n-1; j = i+1, \dots, n, \\ w_i \geq 0, i = 1, \dots, n, \end{cases} \end{aligned} \quad (3)$$

or

$$\begin{aligned} & \text{Max } 1 - \lambda \\ & \text{s.t. } \begin{cases} \ln w_i - \ln w_j - \lambda \ln(m_{ij}/l_{ij}) \geq \ln l_{ij}, i = 1, \dots, n-1; j = i+1, \dots, n, \\ -\ln w_i + \ln w_j - \lambda \ln(u_{ij}/m_{ij}) \geq -\ln u_{ij}, i = 1, \dots, n-1; j = i+1, \dots, n, \\ w_i \geq 0, i = 1, \dots, n. \end{cases} \end{aligned} \quad (4)$$

To avoid membership degree  $\lambda$  from taking a negative value, the nonnegative deviation variables

$\delta_{ij}$  and  $\eta_{ij}$  for  $i=1, \dots, n-1$  and  $j=1, \dots, n$  are introduced such that they meet the following inequalities:

$$\begin{aligned} & \ln w_i - \ln w_j - \lambda \ln(m_{ij}/l_{ij}) + \delta_{ij} \geq \ln l_{ij}, i = 1, \dots, n-1; j = i+1, \dots, n, \\ & -\ln w_i + \ln w_j - \lambda \ln(u_{ij}/m_{ij}) + \eta_{ij} \geq -\ln u_{ij}, i = 1, \dots, n-1; j = i+1, \dots, n. \end{aligned}$$

It is most desirable that the values of the deviation variables are the smaller the better. Accordingly the following nonlinear priority model for weight ( $w_i$ ) derivation is proposed:

$$\begin{aligned} & \text{Min } J = (1-\lambda)^2 + M \cdot \sum_{i=1}^{n-1} \sum_{j=i+1}^n (\delta_{ij}^2 + \eta_{ij}^2) \\ & \text{s.t. } \begin{cases} x_i - x_j - \lambda \ln(m_{ij}/l_{ij}) + \delta_{ij} \geq \ln l_{ij}, i = 1, \dots, n-1; j = i+1, \dots, n, \\ -x_i + x_j - \lambda \ln(u_{ij}/m_{ij}) + \eta_{ij} \geq -\ln u_{ij}, i = 1, \dots, n-1; j = i+1, \dots, n, \\ \lambda, x_i \geq 0, i = 1, \dots, n, \\ \delta_{ij}, \eta_{ij} \geq 0, i = 1, \dots, n-1; j = i+1, \dots, n, \end{cases} \end{aligned} \quad (5)$$

where  $x_i = \ln w_i$  for  $i=1, \dots, n$ , and  $M$  is a specified sufficiently large constant such as  $M=10^3$ .

Let  $x_i^*$  ( $i=1, \dots, n$ ) be the optimal solution to model (5). The normalized priorities for fuzzy pair-wise comparison matrix  $\tilde{A} = (\tilde{a}_{ij})_{n \times n}$  can then be obtained as:

$$w_i^* = \frac{\exp(x_i^*)}{\sum_{j=1}^n \exp(x_j^*)}, \quad i = 1, \dots, n, \quad (6)$$

where  $\exp()$  is the exponential function, namely  $\exp(x_i^*) = e^{x_i^*}$  for  $i=1, \dots, n$ .

Table 2 shows the pair-wise comparison of criteria using linguistic terms defined in Table 1. Thus the fuzzy comparison matrix is formed. In accordance with the previously described method for solving the fuzzy AHP the nonlinear model (5) is solved and by using equation (6) normalized weights of criteria  $w_i$  are derived and shown in Table 2.

In order to determine values of the concepts, in Table 3 is shown the comparison of all pairs of concepts in relation to the criteria, using linguistic terms defined in Table 1. By applying the LFPP method, the preference values of defined concepts in relation to criteria are obtained and shown in Table 4. By including criteria weights from Table 2, final weighted preference values of concepts are obtained based on which is performed the ranking. The final concepts ranking is shown in Table 4.

Solution to the problem of choosing the city logistics concept of Belgrade using FAHP method is the CL4 concept, i.e. the development and implementation of intermodal transport in the function of city logistics.

**Table 2. Pair-wise comparison and criteria weights**

Crit.	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>	C <sub>9</sub>	C <sub>10</sub>	w <sub>i</sub>
C <sub>1</sub>	/	MP	EI	QP	QP	VP	VP	AP	AP	MP	0,335
C <sub>2</sub>	-	/	-	MP	MP	QP	QP	VP	VP	EI	0,112
C <sub>3</sub>	-	MP	/	QP	QP	VP	VP	AP	AP	MP	0,335
C <sub>4</sub>	-	-	-	/	-	MP	MP	QP	QP	-	0,037
C <sub>5</sub>	-	-	-	EI	/	MP	MP	QP	QP	-	0,037
C <sub>6</sub>	-	-	-	-	-	/	EI	MP	MP	-	0,012
C <sub>7</sub>	-	-	-	-	-	-	/	MP	MP	-	0,012
C <sub>8</sub>	-	-	-	-	-	-	-	/	EI	-	0,004
C <sub>9</sub>	-	-	-	-	-	-	-	-	/	-	0,004
C <sub>10</sub>	-	-	-	MP	MP	QP	QP	VP	VP	/	0,112

**Table 3. Concepts comparison by criteria**

Concept	CL1	CL2	CL3	CL4	CL1	CL2	CL3	CL4
Criterion	C1				C6			
CL1	/	MB	VB	VB	/	-	-	-
CL2	-	/	QB	QB	QB	/	-	-
CL3	-	-	/	EG	VB	MB	/	-
CL4	-	-	-	/	AB	QB	MB	/
Criterion	C2				C7			
CL1	/	MB	VB	AB	/	-	-	-
CL2	-	/	QB	VB	QB	/	-	-
CL3	-	-	/	MB	VB	MB	/	-
CL4	-	-	-	/	AB	QB	MB	/
Criterion	C3				C8			
CL1	/	-	-	-	/	-	-	-
CL2	QB	/	-	-	QB	/	-	-
CL3	VB	MB	/	-	VB	MB	/	-
CL4	AB	QB	MB	/	AB	QB	MB	/
Criterion	C4				C9			
CL1	/	-	-	-	/	QB	QB	AB
CL2	QB	/	-	-	-	/	EG	QB
CL3	AB	VB	/	MB	-	-	/	QB
CL4	VB	QB	-	/	-	-	-	/
Criterion	C5				C10			
CL1	/	-	-	-	/	-	-	-
CL2	QB	/	-	-	QB	/	-	-
CL3	VB	QB	/	-	AB	QB	/	EG
CL4	AB	VB	MB	/	AB	QB	-	/

**Table 4. Preference values and concepts ranking**

Criterion	Weight	CL1	CL2	CL3	CL4
C <sub>1</sub>	0,335	0,682	0,227	0,045	0,045
C <sub>2</sub>	0,112	0,708	0,236	0,047	0,009
C <sub>3</sub>	0,335	0,001	0,012	0,104	0,882
C <sub>4</sub>	0,037	0,001	0,012	0,882	0,104
C <sub>5</sub>	0,037	0,001	0,012	0,104	0,882
C <sub>6</sub>	0,012	0,001	0,012	0,104	0,882
C <sub>7</sub>	0,012	0,001	0,012	0,104	0,882
C <sub>8</sub>	0,004	0,001	0,012	0,104	0,882
C <sub>9</sub>	0,004	0,654	0,160	0,160	0,027
C <sub>10</sub>	0,112	0,012	0,090	0,449	0,449
Preference value		0,312	0,118	0,146	0,424
Rank		2	4	3	1

**6. CONCLUSION**

The current situation in Belgrade, in terms of logistics is critical. The problems are various and significant, logistics activities are carried out

routinely and inefficient, and none of the participants take significant initiatives. There are no planning activities, comprehensive and long-term policy of city logistics. Urban planners' decisions are often inadequate, without analysis and overview of different measures and influences.

Four potential city logistics concepts of Belgrade are presented in this paper. Concepts are defined in accordance with the current situation and development plans of the city and economic entities. All concepts represent a complex logistics system therefore all aspects of the application need to be analyzed in order to rank them. Ten criteria are defined for the evaluation of concepts, and for ranking them FAHP method of MCDM is applied in this paper. The CL4 concept, which includes the highest level of concentration and integration, is chosen as the most suitable for solving city logistics problems. This concept has significant advantages in terms of quality of logistics services, the impact on the environment and economic development of the city and the region. However, it requires huge investments, long time and a number of supporting activities for successful implementation.

**ACKNOWLEDGMENT**

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# DETERMINATION NUMBERS OF NODES IN THE POSTAL LOGISTICS NETWORK OF PUBLIC POSTAL OPERATOR

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**Abstract:** *The issuance of network access points and of services to public postal operator is of great importance to customers and other postal operators. In the analysis of most countries in determining the value of access criteria and the number of nodes of the postal logistics network, we came to the following conclusions: models of approach are different and specific for each country. There is no transparent methodology for the definition of particular criteria values (density of access points, minimum number of post offices, distribution/allocation of post offices on urban and rural network and other). In this paper will be defined the criteria related to the density and distribution of network access points and will be determined minimum numbers of nodes in the postal logistics network of public postal operator. Based on the example of the Republic of Serbia, we will propose a model, and test it.*

**Keywords:** *Location, Networks, Postal traffic.*

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## 1. INTRODUCTION

The postal network is defined as “the system of organisation and resources of all kinds used by the universal service provider(s) for the purposes in particular of:

- the clearance of postal items covered by a universal service obligation from access points throughout the territory,
- the routing and handling of those items from the postal network access point to the distribution centre,
- distribution to the addresses shown on items.”

Access points are “physical facilities, including letter boxes provided for the public either on the public highway or at the premises of the postal service provider(s), where postal items may be deposited with the postal network by senders”[5].

The public postal operator's network is the carrier of different logistics costs. Level of logistics costs depends on various factors, that PPO can't always control. Number of units in public network is one factor that has influence on logistics cost level. Postal regulator defines the number of public operator's units, as its location. Determination

number of nodes in postal network is important from the postal clients view.

When defining numbers of nodes in the postal logistics network of public postal operator (Public Postal Network - PPN), the first step that has to be taken is to understand the current and future needs of postal users. Access to universal postal service (UPS) involves the use of access points. Therefore it is necessary to develop criteria that take into account the access to postal services and network, suggesting optimal office hours with users, physical access and other relevant fields. It is necessary, therefore, to define and identify what is important for the community and other factors.

The number and position of facilities in the network where service is provided depends on the type of service (an airport, stations of public transportation, fire brigade, ambulances, police stations, post offices) [1],[16]. In order to define the minimum number and location of nodes in the PPN, we have developed a special methodology and used the original and modified methods to address individual requirements. To measure the distance between the nodes with the requirements for servicing and nodes-candidates for PPN, we used the Euclidean distance formula and the lattice structure. In this paper we have applied the theory of mathematical logic and used the algorithms for

solving requirements problems of location. Algorithm for solving the problem of location requirement has been modified in accordance with the needs of our research.

During the research, we have estimated the importance of certain factors for determining admission criteria. Based on that, we came to a conclusion that it is necessary to make certain measurements and comparisons and systematize the decision making process. In this regard, we suggest that the tests are carried out in several steps:

- Step 1 - Stating the scope of the universal postal service (in some countries in the realm of the universal postal service, in addition to the transfer of letterpost items up to 2kg and parcels up to 20kg, postal and financial services for vulnerable population were included). This step affects significantly the determination of the minimum number of post offices with which Public Postal Operator (PPO) must operate.
- Step 2 – Determining the socio-economic and demographic characteristics of the observed country and establishing the relevant factors for the development of postal services.
- Step 3 – Determining the existing infrastructure of PPO and the structure of the universal postal service's scope and other services provided by PPO.
- Step 4 – Determining the degree of correlation between environmental factors and the requirements for the universal postal service.
- Step 5 - Determining the criteria related to the density, distribution and minimum number of access points, post offices, etc.
- Step 6 - Mapping and testing of access points on the observed territory and determining the minimum number of nodes/units in public postal network.

Based on the example of the Republic of Serbia, we will propose a model of determination numbers of nodes in the postal logistics network of public postal operator, which will also be tested.

## 2. UNIVERSAL POSTAL SERVICE AVAILABILITY

Article 11a of the Postal Directive obliges member states of the EU to provide a transparent, non-discriminatory condition of access and availability of the elements of postal infrastructure or services provided under the universal service [4],

[6]. Regardless of the efforts being made in this direction, there is no universal method for defining the criteria values for the access to services [10]. Requirements in terms of PPN and basic goals (density of access points, the minimum number of permanent post offices, coverage area, and others), that PPOs have to attain are given in Table 1.

**Table 1. PPN, number and position/location of permanent post offices**

PPO	RADIUS	CRITERIA FOR MUNICIPALITY
Czech Republic	Not more than 10km from any location in the municipality to the post office. In villages with more than 2,500 inhabitants, the radius of 2km.	One post office in each municipality with more than 2500 inhabitants; in municipalities with less than 2500 inhabitants if there are joint municipal building and post offices
Deutsche Post	In the districts post office per 80km <sup>2</sup>	1 post office in municipalities with over 2000 inhabitants. office in municipalities with over 4000 inhabitants, the nearest post office at a distance of 2km.
Swiss Post	90% of inhabitants has to walk for 20minutes to the nearest post office, or use public transportation (30 minuta maximum for financial postal services)	

Source: European Regulators Group for Postal Services (2012).

When it comes to the Republic of Serbia, a minimum number of post offices have been mentioned for the first time in 2010 by the **Rules on the conditions for the commencement of postal activities [12]**. It was determined that the PPO is obliged to provide a minimum number of 1400 post offices in order to perform the universal postal service. Their allocation, density and radius of coverage are not considered in this document. Methods and criteria for determining the number and type of postal units are defined in the work of Kujacic et al, 2012 [8]:

- In every settlement with more than 1000 inhabitants and municipality should be provided with at least one permanent post office.
- In settlements with more than 500 inhabitants, but fewer than 1,000 inhabitants, services are made through a mobile UPN (unit of postal network) or postman stand.

- In settlements with less than 500 inhabitants – provision of service is conducted by a postman in a delivery region.
- In settlements with more than 20,000 inhabitants, there has to be at least one permanent UPN on every 20,000 inhabitants.
- Permanent UPN's cannot be farther than 3,000 m from any building in the settlement and the distance between the two UPN in a particular settlement cannot be more than 6,000 m.

Research has shown:

In order to provide universal service, it is essential that PPO has a minimum of 1052 permanent post offices;

For the purposes of 824 settlements with a population of 500-1000, an alternative form of postal network units whose working hours must not be less than 2 hours a day (for example, mobile post office) has to be provided;

If you take into account indicators of development and the fact that there are only a few municipalities that have the status of an urban metropolitan area, it can be concluded that the PPO must have a total of 1052 post offices, of which 360 should be permanent post offices in the urban city area, while other 692 permanent post offices should be allocated in other parts of Serbia (Table 2).

**Table 2. Minimum number of post offices**

	Minimum number of post offices (results of simulation)	Number of post offices in PPO - 2012
Belgrade	157	194
Vojvodina	341	425
Other regions of Serbia	554	863
Total	1052	1482

Source: Kujacic et al. 2012

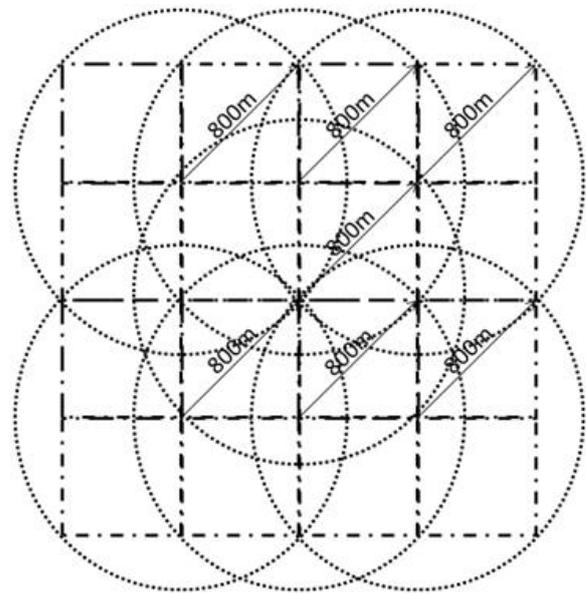
Determination of the minimum number of nodes in settlements with more than 1000 and less than 20000 is relatively easy. The problem arises in determining the number of nodes in settlements with more than 20000, because the next to criteria "on UPN every 20,000 inhabitants," must take into account the urban requirements regarding the distance of UPN [3],[9],[11],[14],[15]. Therefore, we will say a bit more about determining of the minimal number nodes PPN in settlements with more than 20,000 inhabitants.

### 3. METHODOLOGY FOR DETERMINATION NUMBERS OF NODES

Settlements with a population greater than 20,000 are taken into account.

Depending on the requirements in terms of the gravitational areas and the allowed maximum distance of nodes of service from the nodes of demand, the locations of PPN nodes are determined and the total minimum number of PPN nodes [2], [7].

Settlement areas are divided into squares of N zones whose diagonal is 800m, while the radius of a circumscribed circle around 4 square shaped zone (Figure 1). We use Euclidean distance formula.



**Figure 1. Lattice structure**

**STEP 1.** Lattice structure of the settlement is organized in the following manner - vertical and horizontal line are swiped through the focal point, which generates most gatherings; then, grid is "stretched" left/right and up/down from the focal point, so that it covers the entire settlement area. If the focal point cannot be in the settlement, according to the previously defined the manner, place with the most content is taken as a starting point. This is how a network  $G(N, A)$  is obtained, where  $N$  represents the number of nodes,  $A$  is the number of square zones for which stands  $d = 800m$ , covering the surface of the settlement.

**STEP 2.** The values "0" or "1" are assigned to obtained square zones, depending on the urban attributes of observed zones and requirements in terms of coverage radius, i.e. the maximum acceptable distance between the located building in the PPN and the point where demand is generated ("0" for maximum distance up to 800 m and "1" for

maximum distance up to 1600 m). Zones without housing buildings, or, whose percentage of already constructed housing does not exceed 20% of the total area, are not taken into consideration to set up nodes of demand and service. The requirement to determine the radius of the gravitational area is based on the truth of the following statements:

A: The shape of the settlement/zone is an axial shape; B: In the settlement/zone there is a well maintained infrastructure (bicycle and pedestrian path); C: Construction in the settlement/zone is indented; D: The settlement/zone is predominantly single-family residential, E: Settlement/zone has high housing density.

By establishing the logical structure between the evidence, more complex evidence is obtained. Based on this, conclusion is made about the value of the gravitational radius of the zone. The truth value of this complex expression, will indicate the need to define the radius of GP as a value of 1600m, otherwise the value of the radius will be 800m.

**STEP 3.** Zones are compressed into mega zones, such as type MZ4-11, MZ4-01 (1600 m radius) and MZ2-11, MZ2-01 (radius  $800 < r < 1600$ ).

**STEP 4.** In each node in network  $G'(N',A')$ , node is set which generates a service request. There are  $N'$  nodes.

When we define the nodes that require service level and nodes that are candidates for allocation of objects in PPN, the task was further resolved as locational problem with the requirements.

#### 4. RESULTS AND DISCUSSION

When considering the implementation of the proposed model for determining the minimum number of PPN nodes, we have considered the example of settlement in Serbia - Backa Palanka. The settlement has a total population of 28,239[13]. Currently the settlement has three permanent post offices – 3 PPN nodes, of which only one post office performs all kinds of services. According to the model of Kujacic et al, in this settlement there should be a minimum of 2 permanent post offices providing all kinds of services.

In order to determine the minimum number of permanent post offices, based on town-planning requirements, the model presented in Chapter 3 will be used.

Settlement is in a compact shape, with well-kept pedestrian and bicycle paths. Settlement has one focal point. Lettice structure was set in relation to the focal point, which divided this settlement into 66 zones. Diagonal of one zone is 800 m. Figure 2 present the values (0 or 1) for each zone that is

considered. Zones that are marked with "x" are not considered, because they do not have market potential, in this particular case. By compressing the zones, mega zones were obtained: 5 - MZ4-11, 1 - MZ4-01, 2 - MZ2-11. Allowed distance for mega zone is 1600m.

x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x
x	1	1	1	1	1	1	1	1	x	x	x
x	1	1	1	1	0	1	1	1	x	x	x
x	1	1	1	1	1	1	1	1	x	x	x
1	1	1	1	1	1	1	1	1	x	x	x

Figure 2. Values of zones and mega zone

The application of the proposed methodology determined the position and number of permanent post with complete service level (Figure 3).

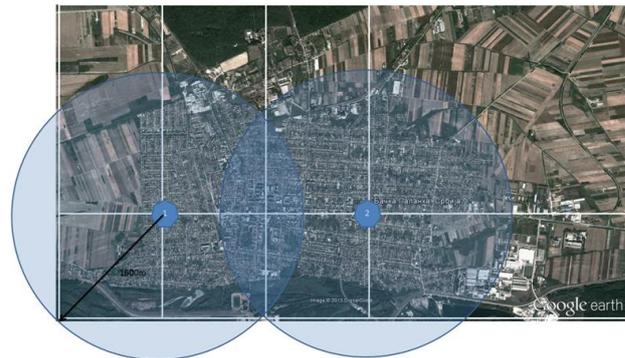


Figure 3. Location of permanent post offices in Backa Palanka

After determining the minimum number of nodes PPN with full service, determined by the availability of services and network for users (Table 3).

In this example, we showed that determining the minimum number of nodes PPN with full service, not decreased the level of service quality. On the contrary, in this example was an increase in the level of quality providing of universal postal services.

In Serbia there are 52 settlements with more than 20,000 inhabitants. By applying the proposed methodology, we have found it necessary to set up 184 post offices (node PPN) for settlements with more than 20,000 inhabitants.

**Table 3. Available with services and network**

CURRENT SITUATION	AFTER DEFINING THE MINIMAL NUMBER OF POST OFFICE WITH FULL SERVICE
1 post office with full service 2 post office with partial service	2 post office with full service
63% of users have access to the post office with full service within a radius of up to 1600m	100% of users have access to the post office with full service within a radius of up to 1600m
34% of users have access to the post office with full service within a radius of up to 800m	72% of users have access to the post office with full service within a radius of up to 800m

## 5. CONCLUSION

Capacity of the public postal network is a strategic advantage of one country, because it allows access to the universal service in the domestic market, while at the same time, supports the expansion and global integration. Maintenance of public postal network has been entrusted to PPO, while also imposing restrictions on the minimum number and allocation of the permanent post offices on the whole territory of the country.

PPN has to meet the requirements of accessibility to users and to effectively cover the entire territory for which it is organized. That was exactly the reason we had developed a model for determining the minimum number of nodes in PPN. Model has its practical significance, as it is suitable for use by regulators of the postal market, as a tool for determining the minimum number of post offices and establishing the basic conditions for access to the postal network.

From this point of view, a combination of described methods and the model are suitable to apply in the optimization of the PPN.

The results obtained by testing the proposed method indicate the possibility of reducing the number of permanent post those providing universal

postal service, while satisfying the required quality in terms of distance and network availability.

Total savings in logistics network cost was not measured in this case, but we can conclude that savings are not low certainly.

Further research in this area should take into account more parameters in the analysis, such as the characteristics of the observed areas, economic, demographic, social characteristics, etc.

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# FINDING LOCATIONS OF DISTRIBUTION CENTRES WITH TIME WINDOW RESTRICTED CUSTOMER REQUESTS

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**Abstract:** *Designing an efficient distribution network is one of the main tasks of supply management today. We consider a case when distribution network contains distribution centres and goods need to be delivered via vehicles to customers with time window constraints. The main goal in the considered problem is determining good locations for distribution centres, together with minimizing their number, the number of vehicles and the total driving time.*

**Keywords:** *cross-docking, location routing problem, time-windows.*

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## 1. INTRODUCTION

One of the major tasks of supply chain management today is an efficient design of distribution networks. In particular, determining good locations for distribution centres via simulations that take customer geographic locations, road network, time and capacity constraints into account is always challenging. An efficient supply chain thus involves high level of synchronization between facility location and vehicle routing decisions. The facility location problem as a strategic problem is often influenced with social, political and economical conditions, consequently reducing the number of potential facility locations to only few locations. On the other hand, vehicle routing as a tactical problem is a subject of daily adjustment to customer's requests.

The necessity of an integrated approach to facility location and vehicle routing problems indicates the paper of Maranzana [5]. A comprehensive research of literature and problem variations of combined location routing problem can be found in the papers of Min Min, Jayaraman and Srivastava [6] and Nagy, Salhi [8]. The papers of Prins and co-authors [9],[10] deal with capacitated location routing problem. As one of the future research directions, the importance of time component, as the essence of the Just-In-Time logistics principle is emphasised in [6]. Only few papers deal with this aspect. In [8] authors argue that

*“time windows relate to a much smaller time horizon than facility location, this horizon mismatch may have deterred researchers from including this aspect”*. Semet and Taillard in [11] considered special case of road-train routing problem. Mirzaei and Krishnan in [7] consider location routing problem with time dependent travel times and time windows. A mathematical formulation of the problem is presented and verified on examples with only few customers. In the paper of Jacobsen and Madsen [4], a two level location routing problem of realistic dimensions was considered. Similarly, in [1],[3] deals with positioning of cross-docking points in newspaper delivery problem.

In this paper we focus on the problem of locating the distribution centres respecting the customer requests and time windows. Therefore, the problem can be classified as a location-routing problem with time windows. Our aim is to solve the large scale problems up to few thousands customers. We define algorithm that simultaneously chooses depot locations and optimizes vehicle routes. The quality of the algorithm is verified on instances with 500-2000 customers.

The rest of the paper is organized as follows: In Section 2 we give the problem description, the proposed solution is presented in Section 3 and the results in Section 4. The conclusion is given in Section 5.

## 2. THE PROBLEM DESCRIPTION

The set of locations  $L$  contains the customers  $C$  and depots  $D$ . For each customer  $i \in C$  we denote request  $r^i$ , time window  $[t_a^i, t_b^i]$  and serving time  $t_s^i$ . Since we do not impose any specific request on the depot locations, we assume that some customer locations are appropriate, and assume  $D \subseteq C$ . However, we suppose that at specific depot a limited quantity of products  $W_d$  can be transferred during a time horizon  $[T_a^d, T_b^d]$ ,  $d \in D$ .

A fleet of homogenous vehicles  $V$  of capacity  $Q$  is available, where  $Q \leq W_d, d \in D$ . We denote by  $R_v = (v^0, v^1, \dots, v^m, v^0)$  a route of vehicle  $v \in V$ . With  $v_a^i, v_d^i$  we denote the arrival and the departure time at location  $v^i$ , respectively, and  $q(v^i)$  represents the quantity of products in vehicle  $V$  departing from  $v^i$ . Let  $dist(v)$  be the total distance of the route of vehicle  $v$ , and  $n(v)$  the number of locations visited. With  $e(s)$  we denote the number of routes starting (and ending) at depot  $d \in D$ .

A route  $R_v$  is feasible if the following holds:

- Starting and ending location is depot,  $v^0 \in D$ ;
- Remaining locations are customer locations,  $v^i \in C, i \in \{1, 2, \dots, m\}$ ;
- All customers on a route are different,  $v^i \neq v^j, i, j \in \{1, 2, \dots, m\}, i \neq j$ ;
- Aggregated request of customers does not violate vehicle capacity constraint  $q(v^0) \leq Q$ ;
- The time constraint at each depot is respected,  $T_a^{v^0} \leq v_d^0 \leq v_a^0 \leq T_b^{v^0}$ ;
- Time constraint at each customer is respected,  $v_a^i + t_s^i \leq t_d^i, v_d^i \leq t_a^i, i \in \{1, 2, \dots, m\}$ .

The distribution plan  $\{R_v, v \in V\}$  is feasible if:

- Each route  $R_v$  is feasible;
- Each customer belongs to exactly one route;
- The aggregated demand of the routes starting at each depot does not violate the depot capacity constraint.

The goal of optimization is to find a feasible distribution plan with minimal distribution costs. The first priority is the number of depots, the second is the number of vehicles and the third is the total distance travelled.

## 3. ALGORITHM

In this section we present the algorithm for solving the location routing problem with time windows. First, we will describe the basic structure of the algorithm and the representation of the solution. Next, we present transformations defining the solution space and finally we describe the algorithm. As a local search procedure we choose Simulated annealing. The algorithm is divided into two main parts. Namely, we distinguish the goal of minimizing the number of depots and vehicles in the first part and minimizing the total distance during the second part.

The basic structure of the algorithm is *Node*. To each customer location we assign two types of nodes: *C-Node* that represents a customer and *D-Node* that represents a depot (we assumed in our test cases that  $C=D$ ). We consider set of  $2|V|+1$  lists. Lists  $l^i, 1 \leq i \leq |V|$ , are the singleton lists containing only one *D-Node*, while  $l_j^i, 1 \leq i \leq |V|, 1 \leq j \leq |V|$ , are the lists containing only *C-Nodes*. Each *Node* belongs to exactly one list, and the *Nodes* contained in the list with index  $2|V|+1$  are not the part of the current solution.

With this structure of the solution we apply the following transformations: Opening a depot location, closing a depot location, and swapping two depot locations. Within the sequence of visited customers we apply the classical routing transformations move, swap, 2-opt and cross. For more details see [2]. We also apply the transformation of moving and swapping two routes.

The algorithm is divided into 3 phases:

- Phase 0 Building the feasible solution;
- Phase 1 Minimization of the number of depot locations and the number of vehicles;
- Phase 2 Minimization of the total distance.

The common evaluation function for all phases can be written in the following form:

$$E(R) = c_1 n(R) + c_2 \sum_{s \in S} e(s)^p + c_3 \ln(m^* + 1) + c_4 dist(R),$$

where  $n(R)$  represents the number of routes, and  $dist(R)$  represents the total route length.

During the Phase 0 and the Phase 1, the algorithm tends to move all customers from the particular vehicle (list). The number of customers on that vehicle is denoted by  $m^*$ . In the Phase 0, a particular vehicle is a dummy that contains all *C-Nodes* and all *D-Nodes*. Therefore, we set  $c_1 = c_2 = 0$ , and  $c_3, c_4 > 0$ . During the Phase 1,

algorithm periodically and randomly chooses a route, and also tends to group routes to few depots. Accordingly we use,  $c_1, c_2 \gg c_3 \gg c_4 > 0$ . Finally in the last phase, algorithm tends to minimize the total distance so we set  $c_1, c_2 \gg c_4 > 0, c_3 = 0$ .

**4. COMPUTATIONAL RESULTS**

The quality of the algorithm was tested on the several test instances generated on 500, 1000 and 2000 customers. The customer request was uniformly generated in  $r^i \in (0,1200]$ , and the time-windows  $t_a^i \in [0,180]$ ,  $t_d^i \in [360,600]$ . Customer's locations are randomly chosen in the radius 10000. The capacity of depots are identical and set to  $W = 40000$ , and vehicle capacity is  $C = 10000$ .

As noted, the local search procedure is Simulated annealing. We apply the geometric cooling schedule scheme in the following way. The initial temperature is  $T = T_0$ , and  $T := T^\theta$  after each  $\tau$  seconds. The algorithm stops if  $T < T_{end}$ . Experimentally we set  $\tau = 10/3$  seconds and  $T_{end} = 0,1$ .

The algorithm was coded in C++, and all tests were performed on Intel Pentium processor 1,6GHz. For each instance we run the algorithm 5 times and compare the best solution found with the average. There were no variation in the number of depots and the number of vehicles found. Therefore, we report best and average values for total distance. Among different cooling parameter  $\theta$ , we report results for two values:  $\theta_1 = 0,99$  and  $\theta_2 = 0,995$ . Table 1 summarizes the testing results for  $\theta_1 = 0,99$ .

**Table 1. The results of testing for  $\theta_1 = 0,99$ .**

Test Instance	Solution			
	$s(R)$	$n(R)$	$min\ dist(R)$	$avg\ dist(R)$
501	8	29	156962	162456
502	8	30	160392	163329
503	8	30	163381	167915
1001	12	46	224045	229894
1002	12	47	223667	229538
1003	12	46	225484	233060
2001	16	61	311867	316705
2002	16	61	302435	314825
2003	16	61	308875	319491

The average running time for the scheme  $\theta_1 = 0,99$  is 1193 seconds and for  $\theta_2 = 0,995$ , 2292

seconds. The comparison of individual and best solution is summarized in Table 3.

In the Table 2 we summarize results for  $\theta_2 = 0,995$ .

**Table 2. The results of testing for  $\theta_2 = 0,995$ .**

Test Instance	Solution			
	$s(R)$	$n(R)$	$min\ dist(R)$	$avg\ dist(R)$
501	8	29	159144	161167
502	8	30	161432	164934
503	8	30	165158	168142
1001	12	46	221551	225215
1002	12	47	225566	232923
1003	12	46	219656	223648
2001	16	61	300738	306922
2002	16	61	303994	309822
2003	16	61	300129	307220

The deviation from best solutions for each cooling parameter ranges from 1,27% to 4,10%. On average, it is 2,88% for  $\theta_1 = 0,99$ , and 2,04% for  $\theta_2 = 0,995$ , and can be characterized as acceptable taking the problem complexity into account.

**Table 3. The average deviation from best solution for  $\theta_1 = 0,99$  and  $\theta_2 = 0,995$ .**

Test Instance	The average deviation in %	
	$\theta_1 = 0,99$	$\theta_2 = 0,995$
501	3,50	1,27
502	1,83	2,17
503	2,90	1,81
1001	2,61	1,65
1002	2,63	3,26
1003	3,36	1,82
2001	1,55	2,06
2002	4,10	1,92
2003	3,44	2,36
Average	2,88	2,04

## 5. CONCLUSION

In this paper we have proposed the algorithm for solving the problem of locating depot locations in distribution networks. The algorithm runs in two phases respecting the optimization goals. Quality of the algorithm was tested on several large scale examples.

As noted, analyzed problem can be seen as a location routing problem with time windows. Testing the algorithm on classical location routing instances may give the insights for directions for further improvements of the algorithm.

In future research, we will analyze possibilities of exploring neighbourhoods with other procedures, e.g. via variable neighbourhood search. Also, reducing problem dimensions by clustering techniques may lead to significant improvements.

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# MATHEMATICAL FORMULATION FOR THE CLOSED LOOP INVENTORY ROUTING PROBLEM

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**Abstract:** *In this paper we observe a closed loop distribution–collection system with a single depot and a set of consumers. Depot has a production facility that produces a single product packed in returnable containers that needs to be delivered to a set of customers. After this product has been used at consumers, returnable containers must be collected and returned to a production facility as an input for the next production cycle. Decision maker must determine, for each day of planning horizon, an exact routing plan for pickup and deliveries in distribution and reverse segment while taking into consideration inventory levels of empty containers and products at depot and consumers. In this paper we present an optimal approach as a mixed integer linear programming model for solving aforementioned closed loop inventory routing problem.*

**Keywords:** *Inventory routing, Simultaneous pickup and delivery, MILP.*

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## 1. INTRODUCTION

A closed loop distribution system considers both forward and reverse flows of material. In this paper we observe one-to-many-to-one type of closed loop system with a single depot and a set of consumers. A production facility is located at depot from where a single product is being distributed to a set of consumers. The products are packed in returnable containers. After the products' consumption, empty containers must be returned from consumers to a depot as an input for the next production cycle. For a single time period, this problem can be described as a well known vehicle routing problem with pickup and delivery (VRP-PD), see [1]. Our intention was to extend this problem to multi period planning horizon and to formulate, to the best of our knowledge, a unique closed loop inventory routing problem with simultaneous pickup and delivery with time windows (IRP-SPD-TW). The inventory routing problem (IRP) is another well known research area that simultaneously considers inventories and vehicle routing to optimize delivery plan in a given planning horizon, and recently it has received significant attention from many researchers. An excellent introduction paper to IRP is given by [2], while importance and reasons for the IRP investigation comparing to VRP is given by [3].

Main reason for observing the IRP is the addition of the time dimension in decision making process, comparing to the VRP that in general depends on the space dimension. The most recent IRP survey is given by [4] thirty years after the publication of the first paper ([5]) that simultaneously observed inventories and vehicle routing.

We developed a mixed integer linear programming (MILP) model to have full mathematical understanding of objective function and side constraints of observed IRP-SPD-TW and to be able to benchmark future heuristic approaches that should be developed.

The remaining part of this paper is organized as follows. The paper background with literature overview is given in Section 2. The mathematical formulation is given in Section 3. Section 4 presents test instances and computational results. Finally, some concluding remarks are given in Section 5.

## 2. BACKGROUND

A growing environmental awareness has lead to reduction of the amount of waste produced and energy consumed in production and distribution systems. These reductions can be achieved by better use of returnable packages, end-of-life and end-of-use products that can be partly or fully disassembled, recycled, remanufactured, and reused. Numerous

legislative regulations among many developed countries demand certain recycling rates, packaging recovery, and active role of manufacturer in the total product lifecycle, which also includes the collection of products. This is the main driving force of reverse logistics, together with costs saving that can be achieved by some kind of product reuse.

Inspiration for our work was the soft drink distribution problem that was observed by [6], and beverage distribution problem that was observed by [7]. In general, bottled drinks (later referred as products) are produced and distributed to a set of consumers. After consumption, empty bottles (later referred as empty containers) must be collected and transported to either recyclable or production facility as an input for next production cycle. Therefore, each consumer has pickup (empty containers) and delivery (products) demands, and this problem is formulated as VRP-PD. Practical application of the VRP-PD can also be found in the case of distribution and collection of books from libraries [8], parcel pickup and delivery service [9], grocery stores replenishment with reusable specialized pallets/containers [10], containership routing [11], home health care [12], printer and photocopier manufacturing industry [13], container drayage [14].

According to [10], in many practical applications costumers that have both pickup and delivery demands want to be serviced with a single stop only, which implies the use of simultaneous pickup and delivery (VRP-SPD) approach. Min [8] was the first author to publish research paper on VRP-SPD.

A prerequisite for IRP is a vendor managed inventory (VMI) system in which supplier makes all decision related to costumers replenishment. As stated by [4], this often leads to a win-win situation where vendors or distributors have more efficient distribution and production, while costumers are freed from inventory control costs. Although the VRP-SPD is intensively being researched, its extension commonly known as inventory routing problem, in this case with simultaneous pickup and delivery (IRP-SPD), is surprisingly unexplored. In the available literature, we didn't found any research papers that consider optimization of both inventories and vehicle routing with simultaneous pickup and delivery over given planning horizon. Additionally, in the practice, pickup and delivery at consumers can only take place on certain time windows, and therefore we observe IRP-SPD-TW.

To the best of our knowledge, four papers were published on the topic of VRP-SPD with time windows (VRP-SPD-TW). The problem observed by [13] is the most similar one to ours, where in general we expanded the problem with a time

dimension, a production facility and an inventory management.

### 3. MATHEMATICAL FORMULATION

In this paper we observe a closed loop logistics system with one-to-many-to-one distribution of a single product and return flow of that product's empty containers. A multi period planning horizon is considered where in each day production should be maximally utilized and consumers' consumption satisfied. Each consumer must be served by a vehicle within a given time window. A production facility is located at depot which generates products that should be delivered to a set of consumers. Inventory level of products and daily consumer's consumption defines required delivery quantity of products as well as possible generated quantity of empty containers at each consumer per each day of planning horizon. Only available products can be consumed and therefore the quantity of empty containers that can be generated in each day at consumer is defined by available products and its daily consumption. In a production facility, each product is packed in a single empty container. Therefore, inventory level of empty containers and daily production capacity defines the necessary quantity of empty containers that should be collected on daily basis from consumers, and transported to a production facility. Vehicles are located at depot where all routes must start and end their routes. In a single route, vehicle can serve both pickup and delivery demands. Consumers can be served by a single vehicle in a single stop in each day of planning horizon for both pickup and delivery. This implies that the VRP-SPD-TW must be solved for each day of a planning horizon. What will be the pickup quantities and delivery quantities for a production facility and each consumer in each day of planning horizon is the core problem in the IRP-SPD-TW. We assume that each consumer can have a time window in which a vehicle can visit and serve pickup and/or delivery demand.

We use the following notation in the proposed MILP model:

#### *Sets*

- $I$  - set of nodes (0 for depot with production facility, 1 and higher for nodes)
- $T$  - set of days in planning horizon
- $V$  - set of vehicles

#### *General parameters*

- $c_{ij}$  - travel distance between nodes  $i$  and  $j$

- $K$  - vehicles' capacity  
 $S_i$  - empty containers inventory level at the beginning of planning horizon in node  $i$   
 $N_i$  - product inventory level at the beginning of planning horizon in node  $i$   
 $P$  - daily production at depot  
 $q_i$  - daily consumption of products in node  $i$   
 $t_{ser}$  - node service time  
 $b_i$  - start of time window for node  $i$   
 $e_i$  - end of time window for node  $i$   
 $M$  - big number in objective function  
 $M_2$  - big number in constraints (23) and (24)

*Decision variables*

- $U^t$  - shortage of empty containers for full productivity of production facility in day  $t$   
 $x_{vi}^t$  - quantity of collected empty containers at node  $i$  with vehicle  $v$  in day  $t$   
 $h_{vi}^t$  - quantity of delivered products at node  $i$  with vehicle  $v$  in day  $t$   
 $z_i^t$  - empty containers inventory level at the beginning of day  $t$  in node  $i$   
 $w_i^t$  - products inventory level at the beginning of day  $t$  in node  $i$   
 $a_i^t$  - realized consumption at node  $i$  in day  $t$  (depends on available products)  
 $r_i^t$  - product shortage at node  $i$  in day  $t$  to satisfy daily consumption  $q_i$   
 $s_{vi}^t$  - arriving time of vehicle  $v$  at node  $i$  in day  $t$   
 $u_{vi}^t$  - total quantity of empty containers accumulated in vehicle  $v$  upon leaving node  $i$   
 $l_{vi}^t$  - total quantity of products remaining in vehicle  $v$  upon leaving node  $i$   
 $y_{vij}^t = \begin{cases} 1 & \text{if vehicle } v \text{ travels directly from node } i \\ & \text{to node } j \text{ in day } t \\ 0 & \text{otherwise} \end{cases}$   
 $p_{vi}^t = \begin{cases} 1 & \text{if vehicle } v \text{ pickup empty containers} \\ & \text{from node } i \text{ in day } t \\ 0 & \text{otherwise} \end{cases}$   
 $d_{vi}^t = \begin{cases} 1 & \text{if vehicle } v \text{ delivers products to} \\ & \text{node } i \text{ in day } t \\ 0 & \text{otherwise} \end{cases}$   
 $f_{vi}^t = \begin{cases} 1 & \text{if vehicle } v \text{ visits node } i \text{ in day } t \\ 0 & \text{otherwise} \end{cases}$

Model formulation presented here primary minimizes shortage of empty containers for full productivity of production facility and shortage of products for full consumption at nodes. Secondly it minimizes vehicles total travel distance. Objective function of the proposed model is defined by (1), subject to constraints (2)-(34).

$$\text{Min} \rightarrow M \cdot \left( \sum_{t=1}^T \left( U^{t+1} + \sum_{i=1}^I r_i^{t+1} \right) \right) + \sum_{t=1}^T \sum_{v=1}^V \sum_{i=0}^I \sum_{j=0}^I c_{ij} \cdot y_{vij}^t \quad (1)$$

Big number  $M$  should be large enough so that a single unit of any shortage is more important than savings in vehicles travel distance.

*Subject to*

$$\sum_{t=1}^T \sum_{v=1}^V x_{v0}^t = 0 \quad (2)$$

$$x_{vi}^t \geq p_{vi}^t \geq \frac{1}{K} \cdot x_{vi}^t \quad \forall t \in T, \forall v \in V, \forall i \in I, i > 0 \quad (3)$$

$$h_{vi}^t \geq d_{vi}^t \geq \frac{1}{K} \cdot h_{vi}^t \quad \forall t \in T, \forall v \in V, \forall i \in I, i > 0 \quad (4)$$

$$p_{vi}^t + d_{vi}^t \geq f_{vi}^t \geq \frac{(p_{vi}^t + d_{vi}^t)}{2} \quad \forall t \in T, \forall v \in V, \forall i \in I \quad (5)$$

Constraints (2) forbid empty containers from production facility. Constraints (3) defines if vehicles  $v$  pickup empty containers from node  $i$  in day  $t$ . Constraints (4) defines if vehicles  $v$  delivers products to node  $i$  in day  $t$ . Constraints (5) defines if vehicles  $v$  visits node  $i$  in day  $t$ .

*Inventory related constraints*

$$z_i^1 = S_i \quad \forall i \in I \quad (6)$$

$$w_i^1 = N_i \quad \forall i \in I \quad (7)$$

$$z_0^{t+1} = z_0^t - P + \sum_{v=1}^V \sum_{i=1}^I x_{vi}^t \quad \forall t \in T \quad (8)$$

$$w_0^{t+1} = w_0^t + P - U^t - \sum_{v=1}^V \sum_{i=1}^I h_{vi}^t \quad \forall t \in T \quad (9)$$

The starting inventory level of empty containers and products at the beginning of planning horizon in all nodes are set by constraints (5), (6). The inventory level of empty containers and products at the end of day  $t$  and beginning of day  $t+1$  in production facility is defined by constraints (8), (9).

$$a_i^1 = q_i \quad \forall i \in I, i > 0 \quad (10)$$

$$a_i^{t+1} = q_i - r_i^{t+1} \quad \forall t \in T, \forall i \in I, i > 0 \quad (11)$$

$$r_i^{t+1} \geq q_i - w_i^{t+1} \quad \forall t \in T, \forall i \in I, i > 0 \quad (12)$$

We set realized consumption to full intensity for the first day of planning horizon by constraints (10). For each following day, by constraints (11) we define the realized consumption for each node.

Inventory shortage of products at each node is defined by constraints (12).

$$z_i^{t+1} = z_i^t + a_i^t - \sum_{v=1}^V x_{vi}^t \quad \forall t \in T, \forall i \in I, i > 0 \quad (13)$$

$$w_i^{t+1} = w_i^t - a_i^t + \sum_{v=1}^V h_{vi}^t \quad \forall t \in T, \forall i \in I, i > 0 \quad (14)$$

The inventory level of empty containers and products at the end of day  $t$  and beginning of day  $t+1$  in each node are defined by constraints (13), (14).

$$U^{t+1} \geq 2 \cdot P - z_0^t - \sum_{v=1}^V \sum_{i=1}^I x_{vi}^t \quad \forall t \in T \quad (15)$$

Quantity of empty container shortage at production facility per each day of planning horizon is defined by constraints (15).

*Routing related constraints*

$$\sum_{v=1}^V f_{vi}^t \leq 1 \quad \forall t \in T, \forall i \in I \quad (16)$$

$$\sum_{v=1}^V x_{vi}^t \leq z_i^t \quad \forall i \in I, i > 0 \quad (17)$$

$$x_{vi}^t \leq K \cdot p_{vi}^t \quad \forall t \in T, \forall v \in V, \forall i \in I \quad (18)$$

$$\sum_{i=1}^I \sum_{v=1}^V h_{vi}^t \leq w_0^t \quad \forall t \in T \quad (19)$$

$$h_{vi}^t \leq K \cdot d_{vi}^t \quad \forall t \in T, \forall v \in V, \forall i \in I \quad (20)$$

Constraints (16) define that one node can be visited by only one vehicle per each day. Constraints (17) defines that empty containers can be picked up from node only if that node is in pickup plan and limits the value of pickup quantity in node  $i$  to available empty containers inventories. Constraints (18) limits the value of pickup quantity in node  $i$  to vehicles capacity. Constraints (19) define the maximal products quantities that can be delivered from depot to all nodes in a single day. Constraint (20) defines that products can be delivered to node only if that node is in delivery plan and that quantity is limited to vehicles capacity.

$$\sum_{j=1}^I y_{vij}^t = f_{vi}^t \quad \forall t \in T, \forall v \in V, \forall i \in I, i \neq j \quad (21)$$

$$\sum_{j=1}^I y_{vji}^t = f_{vi}^t \quad \forall t \in T, \forall v \in V, \forall i \in I, i \neq j \quad (22)$$

$$b_i \cdot f_{vi}^t \leq s_{vi}^t \leq e_i + M_2 \cdot (1 - f_{vi}^t) \quad \forall t \in T, \forall v \in V, \forall i \in I \quad (23)$$

$$s_{vi}^t + y_{vij}^t \cdot (d_{ij} + t_{ser}) \leq s_{vj}^t + M_2 \cdot (1 - y_{vij}^t) \quad \forall t \in T, \forall v \in V, \forall i \in I, \forall j \in I, i \neq j, i > 0, j > 0 \quad (24)$$

Constraints (21) define that sum of all incoming arc to visited node must be equal to one and constraints (22) define that sum of all outgoing arc from visited node also must be equal to one; if a node is not being visited by any vehicle these sums are equal to zero. Vehicles arriving time at nodes must be in given time windows for each node, which is defined by constraints (23). Constraints (24) ensure that a vehicle time of arrival at successor node has greater value than arrival time at predecessor node in one route. Also, these constraints eliminate subtours for each route. Big number  $M_2$  should be large enough so that constraints (24) are always valid for cases when a vehicle does not travel from node  $i$  to node  $j$ . This can be achieved if  $M_2$  is set to maximal working time (we assume that vehicles speed is one minute per unit of distance).

$$u_{v0}^t = 0 \quad \forall t \in T, \forall v \in V \quad (25)$$

$$l_{v0}^t = \sum_{i=1}^I h_{vi}^t \quad \forall t \in T, \forall v \in V \quad (26)$$

$$0 \leq u_{vi}^t + l_{vi}^t \leq K \quad \forall t \in T, \forall v \in V, \forall i \in I \quad (27)$$

$$u_{vi}^t + x_{vj}^t + (1 - y_{vij}^t) \cdot K \geq u_{vj}^t \geq u_{vi}^t + x_{vj}^t - (1 - y_{vij}^t) \cdot K \quad \forall t \in T, \forall v \in V, \forall i \in I, \forall j \in I, i \neq j, j > 0 \quad (28)$$

$$l_{vi}^t - h_{vj}^t + (1 - y_{vij}^t) \cdot K \geq l_{vj}^t \geq l_{vi}^t - h_{vj}^t - (1 - y_{vij}^t) \cdot K \quad \forall t \in T, \forall v \in V, \forall i \in I, \forall j \in I, i \neq j, j > 0 \quad (29)$$

Total quantity of empty containers in vehicle  $v$  upon leaving depot is set to zero by constraints (25) and total quantity of products remaining in vehicle  $v$  upon leaving depot is set by constraints (26) to sum of all delivery quantities for vehicle  $v$  in observed day. Constraints (27) defines the minimal and maximal quantities of products and empty containers in vehicle upon leaving node  $i$ . Constraints (28) defines the quantity of empty containers in vehicle upon leaving node  $j$ . Constraints (29) defines the quantity of products in vehicle upon leaving node  $j$ .

$$U^{t+1} \geq 0 \quad \forall t \in T \quad (30)$$

$$z_i^{t+1}, w_i^{t+1}, r_i^{t+1}, a_i^{t+1} \geq 0 \quad \forall t \in T, \forall i \in I \quad (31)$$

$$x_{vi}^t, h_{vi}^t, u_{vi}^t, l_{vi}^t, s_{vi}^t \geq 0 \quad \forall t \in T, \forall v \in V, \forall i \in I \quad (32)$$

$$p_{vi}^t, d_{vi}^t, f_{vi}^t \in \{0,1\} \quad \forall t \in T, \forall v \in V, \forall i \in I \quad (33)$$

$$y_{vij}^t \in \{0,1\} \quad \forall t \in T, \forall v \in V, \forall i \in I, \forall j \in I, i \neq j \quad (34)$$

Constraints (30)-(32) define decision variables that take positive integer values, and constraints (33) and (34) define the binary nature of decision variables.

#### 4. COMPUTATIONAL RESULTS

In order to test the MILP model we have randomly generated 10 test instances with the following parameters: one production facility and 10 nodes ( $I=10$ ); 2 vehicles that can transport up to 15 units ( $K=15$ ); node consumption can have any integer value from [1, 4]; 60 min node's time window length can begin at any full hour between [60 min, 360 min]; planning horizon of 4 days ( $T=4$ ); the spatial coordinates of nodes are randomly generated as integers in a square [-50, 50] units and the location of the depot is in the center of that square (coordinates (0, 0)); travel distance between nodes  $i$  and  $j$  is calculated as Euclidian distance; productivity of production facility is set to  $P=25$ ; inventory level in production facility at the beginning of planning horizon is randomly generated as integers between  $[P, P + P/5]$  for both products and empty containers; inventory level in each node at the beginning of planning horizon is randomly generated as integers between  $[q_i, q_i*1.5]$ , with additional condition that sum of all node's beginning inventory levels must be between  $P$  and  $P+P/10$  (for both products and empty containers); node service time is set to  $t_{ser}=10$ ; maximum working time is set to 8 hours ( $b_i=0$  min,  $e_i=480$  min); big number in objective function is set to  $M=100$ ; big number in constraints is set to  $M_2=480$ .

Table 1 shows input parameters for instance 1. The solution for instance 1, represented in deliveries and pick-ups at nodes in planning horizon, is given in Table 2. The solution routes for instance 1 is presented in Figure 1.

The results for all 10 test instances are presented in Table 3 which contains: objective function values; sum of all empty containers shortages for full productivity of production facility in planning horizon; sum of all product shortages at nodes in planning horizon; and CPU time.

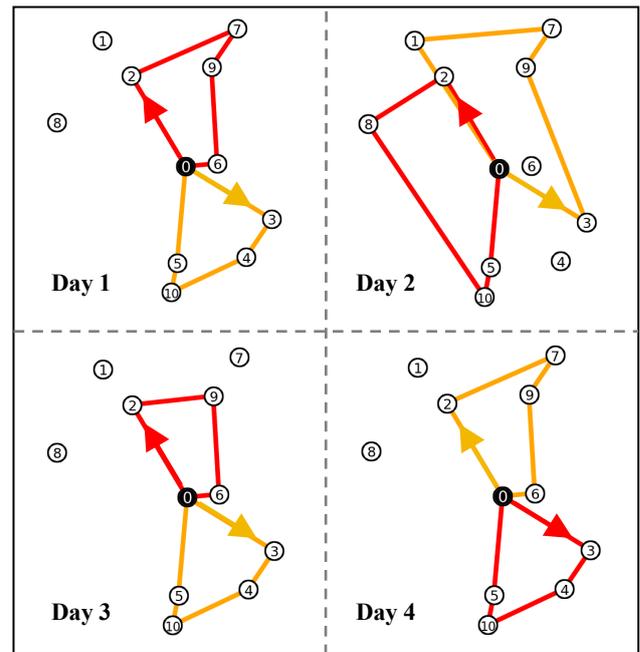
**Table 1. Input parameters for instance 1**

$i$	$x_i$	$y_i$	$S_i$	$N_i$	$q_i$	$b_i$	$e_i$
0	0	0	29	27	-	0	480
1	-29	43	2	2	2	360	420

2	-19	31	4	3	3	180	240
3	30	-18	2	3	2	180	240
4	21	-31	3	3	3	300	360
5	-3	-38	3	3	3	360	420
6	11	1	2	2	2	360	420
7	18	47	1	1	1	300	360
8	-45	15	1	1	1	300	360
9	9	34	4	5	4	300	360
10	-5	-43	4	4	4	360	420

**Table 2. Solution for instance 1: deliveries and pick-ups at nodes in planning horizon**

$i$	$t=1$		$t=2$		$t=3$		$t=4$	
	deliv.	pick.	deliv.	pick.	deliv.	pick.	deliv.	pick.
1	-	-	6	4	-	-	-	-
2	3	4	3	3	5	2	1	4
3	2	2	2	1	2	2	2	2
4	6	3	-	-	3	6	3	3
5	3	1	3	5	3	3	3	3
6	4	2	-	-	4	4	-	2
7	2	1	1	1	-	-	1	2
8	-	-	3	2	-	-	-	-
9	3	4	4	5	4	4	4	4
10	4	4	4	4	4	4	4	4
Total	27	21	26	25	25	25	18	24



**Figure 1. Obtained routes per each day for instance 1**

MILP model was implemented by the CPLEX 12.2 on the Intel(R) Core(TM) i3 CPU M380 2.53 GHz with 6 GB RAM.

#### 5. CONCLUSION

In this paper we developed the MILP model for solving the closed loop inventory routing problem with simultaneous pickup and delivery with time windows with objective to provide continuous supply of the production facility and consumers under minimal transport costs. The MILP model was able to solve 9 out of 10 small scale instances.

Instance 2 could not be solved in maximum allowed CPU time of 1800 sec. This implies that the MILP model is sensitive to instance input parameters. Additionally, CPU time for solving the small scale problems indicate that larger problems could not be solved to optimality in a reasonable time.

**Table 3. Results from the MILP model**

Instance	Obj. func.	$\Sigma U^{t+1}$	$\Sigma \Sigma r^{t+1}_i$	CPU time [sec]
1	1559	1	3	29.6
2	2077	3	4	*1800.0
3	1292	0	0	27.1
4	1419	0	1	101.0
5	1579	0	0	57.3
6	1850	0	1	88.6
7	1222	0	1	239.0
8	1832	0	1	219.0
9	1598	0	0	401.8
10	1505	0	0	99.9
Avg.	1593.3	0.4	1.1	306.3

\* Solution obtained after 1800 sec of CPU time (CPLEX parameter *timelimit* is set to 1800).

Therefore, future research should include comprehensive model testing regarding characteristics of vehicle fleet and time windows as well as development of a heuristic approach for solving larger scale problem instances that are more realistic.

## ACKNOWLEDGMENT

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# MULTI-TRIP VEHICLE ROUTING WITH ORDER COMPATIBILITIES AND ORDER SCHEDULING: A PROBLEM ARISING FROM SUPPLY CHAIN MANAGEMENT

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**Abstract:** In this talk we introduce several new classes of rich vehicle routing problems which are motivated by a real-world problem arising in supply chain management. The problems are based on a specific 2-echelon distribution system where products come to the depot from different factories by semi-trailers and these semi-trailers are also used for short-haul distribution, i.e. the load from different factories is not consolidated at the depots. We specify the problem types and outline our algorithmic approaches used for solving.

**Keywords:** multi-trip vehicle routing, order incompatibilities, supply chain management, meta-heuristic.

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## 1. THE PROBLEM

In this talk we introduce several new classes of rich vehicle routing problems which are motivated by a real-world 2-echelon distribution system arising in supply chain management.

In our application we receive orders from customers for customized production of specific variants of a complex, i.e. voluminous and multipartite product. Depending on the variant these orders are produced in different factories. Deliveries of orders are planned for a planning horizon of  $T$  days.

Every order  $o$  has a certain volume  $\text{vol}(o)$  and it is associated with a factory  $f(o)$  and its customer location  $\text{cust}(o)$ . Distribution is done via a two-echelon channel using a set  $D$  of intermediate depots. Depending on the customer location every order  $o$  has a certain set  $D(o)$  of admissible depots. At the factory (subsets of) orders are loaded onto trailers which are then transported to one of the depots by a factory truck. At the depot the trailer is decoupled and stored overnight. The next day the trailer is coupled to a depot truck which delivers the load on a route that is defined by the reverse loading sequence of the orders loaded on the trailer and which starts and ends at the depot. The factory truck returns to the factory with an empty trailer. Let  $F$  be the set of factories,  $D$  be the set of depots,  $V(f)$  be the set of factory trucks available at factory  $f$  in  $F$

and  $V(d)$  the set of depot trucks available at depot  $d$  in  $D$ .

Trailers have a maximal volume capacity  $Q$  and the daily routes of the depot trucks have a maximum duration of  $Dur$ . Due to the volume of the orders (products) the number of orders which can be packed on a semi-trailer is rather small and the duration of depot routes are relatively short. Therefore a depot truck is able to perform several delivery tours a day. Now the problem is to determine an optimal distribution of a set of fixed orders from the factories to the customers and here minimizing the number of trucks is the primary objective while minimizing the distances travelled is the secondary objective. Thus in our problem we address the cost optimal movement of flows throughout the network from their origins to their destinations as well as the management of the fleets required to provide transportation.

The distribution involves several decisions:

- we have to determine which orders should be distributed on which day (order scheduling),
- for every day and every factory the selected orders have to be assigned to depots (channel selection),
- all orders assigned to the same depot have to be assigned to trailers (clustering),

- the loading sequence of the orders has to be determined since this sequence determines the delivery route from the depot (routing),
- the trailer loads at the depots have to be bundled to multi-trip routes for depot trucks (bundling).

All these decisions are interconnected and have to be done under the objective to first minimize the total number of trucks needed and second to minimize the total driving distance. Thus in its entire complexity the problem is a multi-depot multi-trip vehicle routing problem with order (in-) compatibilities for trips and order scheduling.

The distribution system is illustrated in Figure 1.

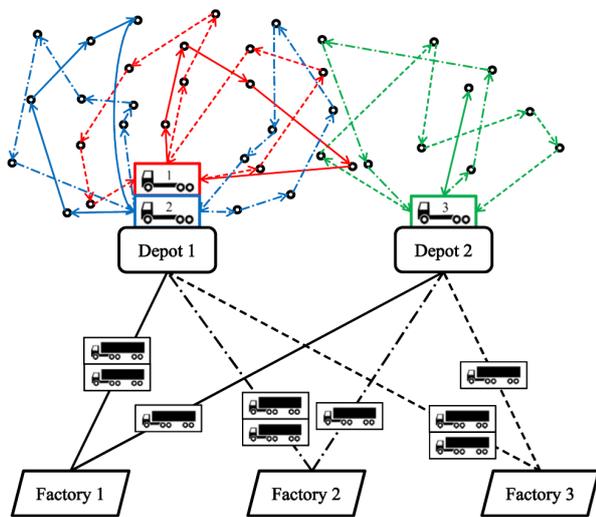


Figure 1. Example of the distribution system

Assume that we have constructed (for every factory) the set of feasible trailer loads, i.e. those assignments of orders to trailers and depots which lead to routings for which maximum load volume is obeyed. Then the problem can be modelled as a set-partitioning problem with the decision variable

$x(l,h,k,t) = 1$  if load  $l$  is delivered by factory truck  $h$  in  $V(f)$  to depot  $d$  and by depot truck  $k$  in  $V(d)$  on day  $t$  in  $T$ , 0 and otherwise.

Although multi-echelon distribution systems have been studied already in the 1980s, see [7], this problem domain has become recognition and importance with the emergence of complex supply chain management concepts integrating the procurement, production and distribution processes. In the applications discussed in literature, as for instance in City Logistics [2], a central aspect is the possibility of consolidating the freight at the depot. In our application such a consolidation which requires unloading and reloading of at least a part of the cargo is not possible. All semi-trailers remain

untouched and the load is delivered by a depot truck in the order given by the loading sequence at the factory. Thus the entire routing is already determined at the factory. The depots do not perform any warehousing activities and do not require complex infrastructure for handling, i.e. the depots are parking lots. This resembles the satellite concept of specific city logistic approaches.

Since cargo can only be consolidated on the level of complete semi-trailers, planning requires the synchronization of all semi-trailer routes to a set of multi-trip routings for the depot trucks.

At its core our distribution problem can be viewed as a multi-trip vehicle problem (MTVRP) as studied in [1], yet, with a specific additional synchronization constraint and a fixed cost term for every single trip accounting for the traveling distance between factory and depot. Here the synchronization constraint requires that only orders of the same factory can be clustered into one trip, i.e. there is a specific type of incompatibilities between orders disallowing joint distribution. Order or product incompatibilities are known from vehicle routing problems with compartments (VRPC) where vehicles with compartments are employed in order to allow transporting inhomogeneous goods together on the same vehicle, but in different compartments (see [3]). Thus our problem can be viewed as a combination of MTVRP and VRPC. Therefore we denote such problems as multi-depot multi-trip vehicle routing problems with (in-) compatibilities (MDMTVRPC).

Note that the underlying real world problem in this study requires several additional synchronization constraints which lead to more complex RVRP variants.

For the general problem with order scheduling given in our application an additional synchronization constraint requires a balanced use of trailers, i.e. the number of loads/trailers transported to a depot has to be equal over the week such that the trailers used on day  $t$  for transporting a load from a factory to a depot are transported back from the depot to the factory on day  $t+2$  and are available for another load on day  $t+3$ .

Our problem is quite complex and it can be relaxed in several aspects. Setting  $T=1$  we obtain a model for a daily planning approach. If  $|D(o)|=1$  for every order the problem decomposes into a number of (single depot) multi-trip problems (MTVRPC). On the other hand the problems can be extended by time window constraints. In the (MD)MTVRPC with time windows (TW) we have to find for every depot a set of trips such that time window constraints at the customers are met and two trips

that overlap in time cannot be served by the same truck.

## 2. THE SOLUTION APPROACH

In former research on several complex rich vehicle routing problems we have experienced that heuristic approaches combining local search (LS) and large neighborhood search (LNS) easily improve the individual methods and we could show that concurrent LS/LNS neighborhood search (CNS) which combines LS and LNS moves concurrently is highly effective and efficient for solving RVRP variants (see [5]). In [4] we show that this approach outperforms variable neighborhood search (VNS) developed in [8] if the same portfolio of moves is used.

In [5] we describe the implementation of a general CNS software framework allowing customizing appropriate solvers for different classes of rich vehicle routing problems. In our research reported here we have built upon and extended this framework.

LS is based on moves/neighborhoods which allow only small modifications to the current solution and thus supports intensification. The framework contains generic implementations for the following set of moves which have shown to be effective in many LS-approaches for solving different RVRP presented in literature: Relocate, RelocateI, Exchange, 2-opt and 2-opt\*. LNS ( see [9]) implements the ruin-and-recreate principle by combining different removal and insertion operations by which orders are removed from the solution (their tours) first and then reinserted again into the solution. Thus LNS supports diversification. In our framework we combine Random removal, Worst removal and Shaw removal with Greedy insertion and Regret  $n$  (with  $n=2, \dots, 5$ ) insertion. For a detailed description of the LS- and LNS-moves see [5] and [9], respectively.

The acceptance of a neighbour generated by a move is decided by a metaheuristic strategy which guides the search and prevents (early) termination in a (bad) local optimum. In our framework we have implemented record to record travel (RRT) a deterministic annealing techniques and the attribute based hill climber (ABHC) a specific variant of tabu search (TS).

In RRT (see [6]) randomly selected neighbours are accepted if they are not worse than the best solution found so far by a prespecified relative deviation.

In tabu search entire neighbourhoods are scanned and a move to the best neighbour is performed even

if it does not lead to an improvement. In order to prevent cycling solutions are temporarily declared tabu for a number of iterations. ABHC (see [11]) is a parameter-free TS-variant. It uses a generic attribute concept for specifying non-tabu neighbors, which has to be specialized for every problem domain. Then a solution is acceptable if it is the best solution visited so far for at least one attribute that it possesses.

Based on these concepts we have developed two generic concurrent approaches: CNS-ABHC and CNS-RRT. In both methods we start with the construction of an initial solution in a first phase followed by an improvement phase which is applied until a predefined time or iteration limit is reached. In each iteration of the improvement phase we decide randomly which type of neighborhood, i.e. LS or LNS, to use. Then the resulting neighbor is accepted using either metaheuristic control. Specifying a probability parameter  $p^{LS}$  the selection is biased towards either LS or LNS. In LNS we apply a fast 2-opt steepest descent improvement to all modified routings. Figure 2 displays the general logic of CNS.

The framework provides a complete and ready-to-use solver suite for the standard capacitated vehicle routing problem offering several mechanism (templates) to be adapted or extended according to the vehicle routing problem variant to be solved. Thus when solving a specific VRPs like the ones discussed here one has for instance to modify the moves such that the specific constraints, i.e. route duration, order compatibilities etc. are obeyed.

## 3. COMPUTATIONAL EXPERIENCE

Since the MTRPC is a new VRP class there is no set of benchmark instances in the literature which we can use for our computational tests. Therefore we have generated benchmark instances for the MTRPC, the MTRPCTW and the MDMTRPCTW based on the instance set of Solomon [10] for the VRPTW. These benchmark problems assign geographical coordinates to customers, i.e. distances are euclidean. For our problem we assume that each customer requires the delivery of exactly one order.

On these instances we have compared the two CNS-implementations with a basic LNS-RRT implementation. Note, that we have customized the specific approaches while using the standard parametrization identified in [5] to be appropriate for the VRP. Our computational tests were performed on an Intel Xeon E5430 2.66 GHz PC with eight cores and operating system Microsoft Windows 7.

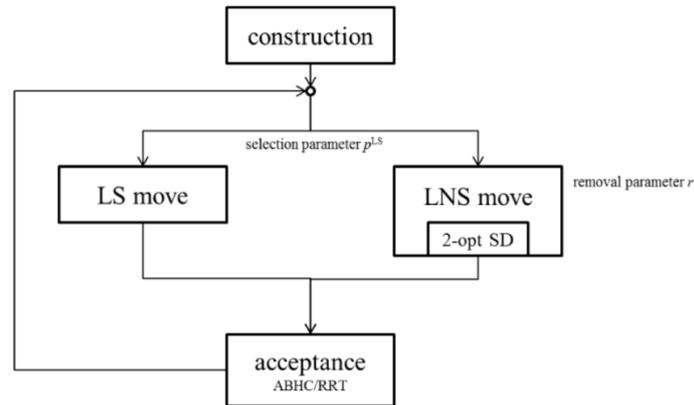


Figure 2. Logic of CNS

The computational results are as expected:

- cost (total traveling distance) for MTVRPCTW increases compared to MTVRPC, yet,
- cost decreases again for MDMTVRPCTW.
- LNS-RRT and CNS-RRT are converging much faster than CNS-ABHC, but
- CNS-ABHC is able to find significantly better solutions under more running time.
- CNS-RRT and LNS-RRT perform relatively similar, yet, CNS-ABHC is able to reduce the fleet size.
- With increasing complexity of MTVRPCTW and MDMTVRPCTW all approaches need longer running times to the point of convergence, but again CNS-ABHC is able to find better solutions consistently.
- Especially, for the MDMTVRPCTW, with RRT one is able to find solutions with shorter total traveling distances (cost) than ABHC, but the number of trucks is smaller for ABHC.

We attribute the last property to the higher potential of diversification under ABHC in comparison to RRT. ABHC is able to accept moves that increase the objective function value significantly and thus ABHC is able to steer the search into areas of the solution space that under RRT are not in reach.

#### 4. CONCLUSION

After all, we could show that as for many other VRP-classes (see [4] and [5]) CNS is a rather effective and efficient strategy for the problem types described in this paper, too. Thus from this feasibility study we can expect that instances of the specific real world 2-echelon problem which has been the motivation of the study can be solved by

our approach satisfying the requirements of effectiveness (solution quality) and efficiency (solution time).

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# OPEN TRAVELING SALESMAN PROBLEM WITH TIME WINDOWS

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**Abstract:** Routing and scheduling of vehicles are important operational issues in the logistic management. This paper deals with the open traveling salesman problem with time windows (OTSPTW). The OTSPTW is an extension of classical traveling salesman problem that is well known in optimization. The goal of the OTSPTW is to find optimal shortest route (in time or distance units) for a vehicle with unlimited capacity in order to serve a given set of customers. The difference of the OTSPTW from the classical TSP model is that the vehicle do not need to return to the depot after a service of the last customer and all the customers need to be served between a given time interval (time window). In this paper, we formulate a mathematical model to capture all aspects of that problem based on mixed integer programming (MIP) with linear objective function and constraints and we present the source code for General Algebraic Modeling System (GAMS).

**Keywords:** Open Traveling Salesman Problem with Time Windows, Mixed Integer Programming, General Algebraic Modeling System.

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## 1. INTRODUCTION

Logistics is evidently one of the major dimensions of many firms and the related logistic costs constitute a significant share of the total costs of every organization. Many variants of routing and scheduling problems that can be very rewarding are known in the field of logistics. The well-known traveling salesman problem (TSP) is one of the most discussed problems in operation research. The importance of that problem is evidently seen in the field of operation research or artificial intelligence etc., because of its computational complexity, but also the importance follows from a great practical applicability, that why the problem can be applied in more general way.

This paper describes the open traveling salesman problem (OTSP). The OTSP is a popular problem in the field of distribution management and can be used to model many real-life problems. For example if the company deals without its own vehicle fleet and has to hire some vehicle to deliver its products to customers. In this case, the company is not concerned whether the vehicle returns to the depot, and does not pay the traveling costs between the last

customer and the depot. The OTSP can be described as follows: Consider a depot from that some products have to be delivered to a set of customers. Products are loaded on a vehicle at the depot and they are transported to the customers. The capacity of vehicle is unlimited, so that all customers' demand can be satisfied with the one route of the vehicle. As the vehicle is hired, after end of a route, vehicle does not need to return to the depot and the delivery process is terminated as soon as the final customer is served. We assume that the shortest distance between depot and each customer's location is known, as well as between each pairs of customer's location is known. The goal is to find optimal shortest route for a vehicle.

The practical problems of physical distribution often include the need to respect the time restriction. Frequently we consider time restriction that are a consequence of first possible time of service, the last acceptable time of service or the need to serve during the given time interval. The above mentioned terms are known as time windows. So we can talk about the open travelling salesman problem with time windows (OTSPTW). If it is necessary to consider only the first possible time of service or the last acceptable time of service, the problem is known

as problem with soft delivery time windows, if we are dealing with time interval with given lower and upper limit, those problems are known as problems with hard delivery time windows, e. g. [5]. Another description of soft windows can be found e.g. in [3], [8], [9], where the violation of time restriction is allowed, although incurring some cost. In formulation of that problem we consider that the shortest travel time between depot and each customer's location is known, as well as between each pairs of customer's location is known.

## 2. THE OPEN TRAVELING SALESMAN PROBLEM

The OTSP can be stated as follows: Consider a network with  $n$  nodes. Indices  $i$  and  $j$  refer to customers and take values between 2 and  $n$ , while index  $i = 1$  refers to the depot. Also there is a shortest distance  $d_{ij}$ ,  $i, j = 1, 2, \dots, n$  associated with the each pair of customers and also with the each customer and the depot. The goal is to find a shortest route for a vehicle with an unlimited capacity that served all the customers so that the route ends after the final customer is served. Mathematical programming formulation of OTSP requires two type of variables: the binary variables  $x_{ij}$ ,  $i, j = 1, 2, \dots, n$  with a following notation:  $x_{ij} = 1$  if customer  $i$  precedes customer  $j$  in a route of the vehicle and  $x_{ij} = 0$  otherwise. Further on, we will apply the variables  $u_i$ ,  $i = 2, 3, \dots, n$  that based on well-known Tucker's formulation of the traveling salesman problem:

Then, the mathematical model for OTSP is:

$$\min \sum_{i=1}^n \sum_{j=1}^n d_{ij} x_{ij} \quad (1)$$

subject to

$$\sum_{i=1}^n x_{ij} = 1 \quad j = 2, 3, \dots, n \quad i \neq j \quad (2)$$

$$\sum_{j=2}^n x_{ij} \leq 1 \quad i = 1, 2, \dots, n \quad i \neq j \quad (3)$$

$$\sum_{j=2}^n x_{1j} = 1 \quad i = 2, 3, \dots, n \quad (4)$$

$$u_i - u_j + nx_{ij} \leq n - 1 \quad i, j = 2, 3, \dots, n \quad i \neq j \quad (5)$$

$$x_{ij} \in \{0, 1\} \quad i, j = 1, 2, \dots, n \quad i \neq j \quad (6)$$

The objective function (1) models the total distance of vehicle route. Constraints (2) ensure that

the vehicle enters to every customer and constraints (3) ensure that the vehicle does not need to depart from every customer, because the route ends after serving the last of them. Constraints (4) ensure that the vehicle starts its route exactly once and constraints (5) avoid the presence of sub-tour.

Source code for GAMS (General Algebraic Modelling System) for solving of OTSP is as follows:

```
$title Open Travelling Salesman Problem
$ontext
Input data
$offtext
Sets
i /1*n/
subi(i) /2*n/
alias (i,j)
alias (subi,subj);
Sets offdiag1(i,j)
offdiag2(i,j);
offdiag1(i,j)=yes;
offdiag1(i,i)=no;
offdiag2(i,j)=offdiag1(i,j);
offdiag2(i,'1')=no;
* Matrix of shortest distances (diag. elements = 0)
Table d(i,j)
;
$ontext
Mathematical model
$offtext
Scalar n;
n=card(i);
Variables f, u(j);
u.fx('1')=0;
u.lo(subi(i))=1;
u.up(subi(i))=n;
Binary variables x(i,j);
Equations
ohr1(i), ohr2(j), anti(i,j), ohr3, ucel;
ucel.. f=e=sum((i,j),d(i,j)*x(i,j));
ohr1(i).. sum(subj(j),x(i,j)$offdiag1(i,j))=1;
ohr2(subj(j)).. sum(i,x(i,j)$offdiag1(i,j))=e=1;
ohr3.. sum(subj(j),x('1',j))=e=1;
anti(i,j)$offdiag2(i,j).. u(i)-u(j)+n*x(i,j)=1=n-1;
Model otsp /all/;
Solve otsp using mip minimizing f;
Display x.l;
```

## 3. THE OPEN TRAVELING SALESMAN PROBLEM WITH TIME WINDOWS

Further on, we will consider the time window for each customer, so that there is known a given time interval  $\langle e_i; l_i \rangle$ , where  $e_i$  represents the first possible time to serve  $i$ -th customer and  $l_i$  represents the last acceptable time to leave the  $i$ -th customer,  $i = 2, 3, \dots, n$ . Also, there is known a service  $o_i$  time of each customer,  $i = 2, 3, \dots, n$ . The variable  $w_i$ ,  $i = 2, 3, \dots, n$ ,

represents a possibility of waiting by a next customer if a service is not allowed. Parameters  $d_{ij}$ ,  $i, j = 1, 2, \dots, n$  associated with the each pair of customers and also with the each customer and the depot represent the shortest travel times.

Thus, the mathematical models can be stated as follows:

$$\min \sum_{i=1}^n \sum_{j=1}^n d_{ij} x_{ij} + \sum_{i=2}^n o_i + \sum_{j=2}^n w_j + v \sum_{i=2}^n u_i \quad (7)$$

subject to

$$\sum_{i=1}^n x_{ij} = 1 \quad j = 2, 3, \dots, n \quad i \neq j \quad (8)$$

$$\sum_{j=2}^n x_{ij} \leq 1 \quad i = 1, 2, \dots, n \quad i \neq j \quad (9)$$

$$\sum_{j=2}^n x_{1j} = 1 \quad i = 2, 3, \dots, n \quad (10)$$

$$u_i + o_i + w_j + d_{ij} - M(1 - x_{ij}) \leq u_j \quad (11)$$

$$i = 1, 2, \dots, n \quad j = 2, 3, \dots, n \quad i \neq j$$

$$e_i \leq u_i \quad i = 2, 3, \dots, n \quad (12)$$

$$u_i + o_i \leq l_i \quad i = 2, 3, \dots, n \quad (13)$$

$$u_1 = 0 \quad (14)$$

$$o_1 = 0 \quad (15)$$

$$x_{ij} \in \{0, 1\} \quad i, j = 1, 2, \dots, n \quad i \neq j \quad (16)$$

$$w_j \geq 0 \quad j = 2, 3, \dots, n \quad (17)$$

where  $M$  – represents a large positive number

As mentioned earlier, constraints (8) ensure that the vehicle enters to every customer and constraints (9) ensure that the vehicle does not need to depart from every customer, because the route ends after serving the last of them and constraints (10) ensure that the vehicle starts its route exactly once. Constraint (5) is replaced by constraints (11) that is there not only to avoid the presence of sub-tour, but also to ensure the calculation of the real starting time of service for each customer (variables  $u_i$ ) and concurrently with the use of constraints (12) and (13) ensure that all the time windows are met. Constraint (14) denotes that the service begins in zero service time and constraint (15) denote the zero service time in the depot. The objective is calculated as a sum of total time, the time of waiting and the

time of service. The formula  $v \sum_{i=2}^n u_i$  in the objective

function ensures the calculation of the lowest values of variables  $u_i$ , without this formula that model can return alternative solution of variables  $u_i$  that do not ensure the calculation of real starting of service of customers (parameter  $v$  is a weight, usually a small number). The total time of service can be calculated by subtracting the weighted value of the sum of  $u_i$  from the value of objective function (7).

Source code for GAMS for solving of OTSPTW is as follows:

```

$title Open Traveling Salesman Problem with Time
Windows
$ontext
Input data
$offtext
Sets
i /1*n/
subi(i) /2*n/
alias (i,j)
alias (subi,subj);
Sets offdiag1(i,j)
offdiag2(i,j);
offdiag1(i,j)=yes;
offdiag1(i,i)=no;
offdiag2(i,j)=offdiag1(i,j);
offdiag2(i,'1')=no;
Scalars M /M/
v /v/;
* Matrix of shortest travel times (diag. elements = 0)
Table d(i,j)
;
Parameters
e(j) //
l(j) //
o(j) //;
$ontext
Mathematical model
$offtext
Scalar n;
n=card(i);
Binary variables x(i,j);
Positive variables w(i);
Free variable f,u(i);
u.fx('1')=0;
Equations
ohr1(i), ohr2(j), ohr3, ohr4(i,j), ohr5(j), ohr6(j), ucel;
ucel..
f=e+sum((i,j),d(i,j)*x(i,j))+sum(subi(i),o(i))+sum(subi(i),
w(i))+v*sum(subi(i),u(i));
ohr1(i).. sum(subj(j),x(i,j)$offdiag1(i,j))=1=1;
ohr2(subj(j)).. sum(i,x(i,j)$offdiag1(i,j))=e=1;
ohr3.. sum(subj(j),x('1',j))=e=1;
ohr4(i,j)$offdiag2(i,j).. u(i)+o(i)+w(j)-u(j)+d(i,j)-M*(1-
x(i,j))=1=0;
ohr5(subj(j)).. u(j)+o(j)=l=l(j);
ohr6(subj(j)).. u(j)=g=e(j);

```

Model otsptw /all/  
Solve otsptw using mip minimizing f;  
Display x.l,u.l,w.l;

#### 4. CONCLUSION

In this paper, we have considered a relative new problem, the open traveling salesman problem with time windows, which addresses practical issues in routing vehicle fleets. The problem was formulated on the base of mixed integer programming (MIP) with linear objective function and constraints. So that formulation allows the use of standard software for solving MIP problems.

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# SOLVING THE VEHICLE ROUTING PROBLEM WITH TIME WINDOWS BY BEE COLONY OPTIMIZATION METAHEURISTIC

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***Abstract:** The vehicle routing problem with time windows is studied in the paper. This problem has been solved by Bee Colony Optimization metaheuristic. Proposed algorithm has been tested on the set of well-known benchmark examples. Obtained results show that the presented algorithm can find high-quality solutions.*

***Keywords:** Vehicle Routing Problem, Time Windows, Bee Colony Optimization.*

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## 1. INTRODUCTION

Different versions of vehicle routing and scheduling problems on the network appear in all fields of transportation and logistics. Well-organized vehicle routing and scheduling can significantly contribute towards a decrease in transportation costs and increase the quality of transportation and logistic services. Numerous papers have been published in world literature during the past five decades treating different aspects of the vehicle routing problems (VRP). Significant reviews are given in the following papers: [3], [10], [12], and [20]. According to the vehicle routing problem definition every node is described by a certain *demand* (the amount to be delivered to the node or the amount to be picked up from the node). Other known values include the *coordinates* of the depot and nodes, the *distance* between all pairs of nodes, and the *capacity* of the vehicles providing the service. Vehicles leave the depot, serve nodes in the network, and after completion of their routes, return to the depot. The classical vehicle routing problem consists of finding the set of routes that minimizes transport costs.

In this paper we study the Vehicle Routing Problem With Time Windows (VRPTW). In the case of VRPTW there is the additional restriction that a time window is associated with each node ([4], [5]). This problem occurs in daily logistics activities, so it is obvious importance of its solving.

Since Bee Colony Optimization (BCO) metaheuristic has become very powerful tool for solving hard combinatorial optimization problems, the authors decide to use it as a tool for solving VRPTW. BCO is a stochastic, random-search technique that belongs to the class of population-based algorithms. This technique uses an analogy between the way in which bees in nature search for food, and the way in which optimization algorithms search for an optimum of (given) combinatorial optimization problems.

The paper is organized as follows. Section after Introduction provides brief description of Bee Colony Optimization algorithm. Content of the following Section presents implementation of the BCO for VRPTW. Section named Numerical results contains experimental evaluations and the last Section brings conclusions related to the research.

## 2. BEE COLONY OPTIMIZATION

The Bee Colony Optimization metaheuristic has been introduced in the papers: [13], [14], [15] and [16]. Up to now BCO has been successfully applied to various engineering and management problems.

The basic idea behind BCO is to build the multi agent system (colony of artificial bees) that will search for good solutions of various combinatorial optimization problems exploring the principles used by honey bees during nectar collection process. Artificial bee colony usually consists of small

number of individuals, but nevertheless, BCO principles are gathered from the natural systems. Artificial bees investigate through the search space looking for the feasible solutions. In order to find the best possible solutions, autonomous artificial bees collaborate and exchange information. Using collective knowledge and information sharing, artificial bees concentrate on the more promising areas, and slowly abandon solutions from the less promising ones. Step by step, artificial bees collectively generate and/or improve their solutions. The BCO search is running in iterations until some predefined stopping criterion is satisfied.

In the BCO algorithm every artificial bee generates one solution to the problem. Artificial bees generate/improve solutions in iterations. Each iteration consists of a certain number of *forward* and *backward* passes (Figure 1). In each forward pass, every artificial bee explores the search space. It applies a predefined number of moves, which construct and/or improve the solution, yielding to a new solution. Having obtained new solutions, the bees go again to the nest and start the second phase, the so-called backward pass. In the backward pass, all artificial bees share information about their solutions, i.e. they make known the quality of the generated solution (the objective function value). Through the backward pass, every bee decides with a certain probability whether to abandon the created solution and become uncommitted follower, or dance and thus recruit the nestmates before returning to the created solution (bees with higher objective function value have greater chance to continue its own exploration). Every follower, choose a new solution from recruiters by the roulette wheel (better solutions have higher probability of being chosen for exploration). The two phases of the search algorithm, forward and backward pass, are performed iteratively, until a stopping condition is met.

The BCO algorithm underwent numerous changes trough the process of evolution from its development, in 2001, until nowadays. Moreover, in order to solve hard combinatorial problems, the initial constructive BCO ([7], [8], [9], [13], [14], [15], [16]) was modified and a new concept based on the improving complete solutions ([6], [18], [19], [20]). was developed. Due to the nature of VRPTW problem, the authors decide to apply improvement version of BCO algorithm. The inputs of the BCO algorithm are:

- $B$  – the number of artificial bees,
- $IT$  – the number of iteration,
- $NP$  – the number of the forward and backward passes in a single iteration,

$NC$  – the number of changes in one forward pass.

The output of the algorithm is:

$S$  – the best obtained solution.

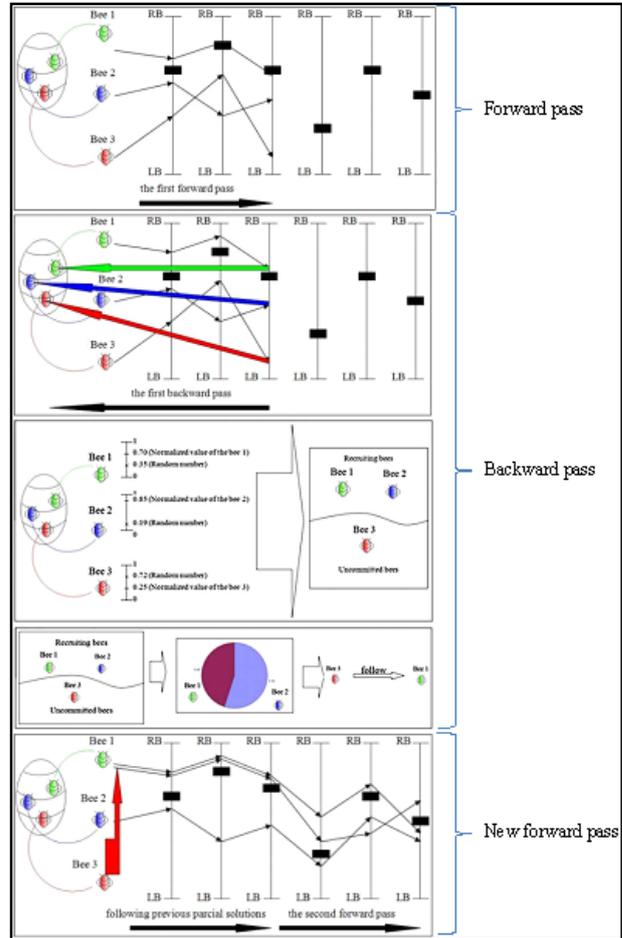


Figure 1. Forward and backward pass

The pseudo code of the BCO algorithm could be described in the following way:

*procedure* BCO(in  $B$ ,  $IT$ ,  $NP$ ,  $NC$ , out  $S$ )

Determine the initial solution.

$S \leftarrow$  set the initial solution.

**for**  $j = 1$  to  $IT$  **do**

**for**  $i = 1$  to  $B$  **do**

    the bee  $i \leftarrow$  the best solution  $S$ .

**for**  $k = 1$  to  $NP$  **do**

**for**  $i = 1$  to  $B$  **do**

**for**  $r = 1$  to  $NC$  **do**

        Evaluate possible changes in the solution of the bee  $i$ .

        Taking into account evaluated values choose one change.

**if** the best solution generated by the bees is **better** than the solution  $S$

**then**

$S \leftarrow$  the best bee's solution.

**For**  $i = 1$  to  $B$  **do**

      Evaluate solution of the bee  $i$ .

**For  $i = 1$  to  $B$  do**  
*Make a decision whether the bee  $i$  is loyal.*  
**For  $i = 1$  to  $B$  do**  
**if the bee  $i$  is not loyal then**  
*Chose one of the loyal bees that will be followed by the bee  $i$*

$$C_{iuj}^1 = d_{iu} + d_{uj} - w d_{ij} \quad (2)$$

where:

$w$  is the parameter (The larger  $w$ , the more emphasis is put on the distance between the vertices to be connected.).

The second type of bees calculate cost as:

$$C_{iuj}^2 = w_1 C_{iuj}^1 + w_2 l_s (t(j/u) - t(j)) \quad (3)$$

where:

$w_1$  and  $w_2$  are the weighting coefficients ( $w_1 + w_2 = 1$ ),

$l_s$  – is the parameter that depends on the insertion location:  $l_s = 1 - \frac{s}{n+1}$ , where  $s$  is the sequential number in the route where node  $u$  should be inserted and  $n$  is the total number of nodes in the route.

$t(j)$  – arrival time at node  $j$  before inserting customer  $u$  in the route between  $i$  and  $j$ ,

$t(j/u)$  – arrival time at node  $j$  after inserting customer  $u$  in the route between  $i$  and  $j$ .

The bees of the third type calculate cost as:

$$C_{iuj}^3 = w_1 C_{iuj}^1 + w_2 (t(j/u) - t(j)) + w_3 (f(u) - t(u)) \quad (4)$$

where:

$f(u)$  – beginning of the service time at node  $u$ ,

$w_1, w_2$  and  $w_3$  are weighting coefficients ( $w_1 + w_2 + w_3 = 1$ )

### 3.3 Backward pass

All bees return to the hive after generating the solutions. All these solutions are then evaluated by all bees. (The total length of all routes characterizes every generated solution). We denote by  $O_i$  normalized value of the total length of all routes generated by the bee  $i$ :

$$O_i = \frac{T_{\max} - T_i}{T_{\max} - T_{\min}}, \quad (5)$$

where:

$T_i$  – the objective function value (the total length of all routes) generated by the bee  $b$ ,

$T_{\max}$ - the highest among all objective function values generated by all bees ( $T_{\max} = \max_{i=1,n} \{T_i\}$ ),

$T_{\min}$ - the lowest among all objective function values generated by all bees ( $T_{\min} = \min_{i=1,n} \{T_i\}$ ).

The probability that  $i$ -th bee (at the beginning of the new forward pass) is loyal to the previously discovered solution is calculated in the following way:

$$p_i = e^{-(O_{\max} - O_i)} \quad (6)$$

## 3. THE BCO APPROACH TO THE VRPTW

In this paper, we propose the BCO heuristic algorithm tailored for the VRPTW. We propose the BCO algorithm that is based on the improvement concept. In other words, we first generate the initial feasible solution (the initial set of routes). Then, artificial bees investigate solution space in the neighborhood of the current solution, and try to improve the solution. The modification of solution is performed through  $NP$  forward passes with in the single iteration. We assume that at the beginning of a route design, all bees are in the artificial location-hive.

### 3.1 The initial solution generation

We use simple insertion heuristic to generate the initial solution. Our heuristic represents modification of the heuristic proposed in [2]. We simultaneously determine insertion location and the node that should be inserted in the route. We determine the first node in the route in a random manner. After that, all other nodes are inserted in the route according to insertion cost. We calculate the cost of insertion of node  $u$  between nodes  $i$  and  $j$  in the following way:

$$C_{iuj} = d_{iu} + d_{uj} - d_{ij} \quad (1)$$

where:

$d_{ij}$  is the distance between nodes  $i$  and  $j$ .

The node with the lowest cost is inserted between the corresponding two nodes. If neither of unrouted nodes can be inserted in the route, the new route will be open, and the process will continue until the set of unrouted nodes is not empty.

### 3.2 Solution modification

We modify the solution in the way that couple of routes are removed and the nodes in these routes became unrouted. After that, we use insertion heuristic to make the new routes.

The paper [2] presented three insertion heuristics. The difference between them are in a way they calculate costs. Following the idea of these three insertion heuristics, we use three types of artificial bees.

The bees of the first type calculate cost as:

where:

$O_{\max}$  – maximum among all normalized values  
 $(O_{\max} = \max_{i=1,n} \{O_i\})$

If bee decides not to stay loyal to its previous solution, it should decide about the loyal bee she should follow. The probability that the bee will follow the loyal bee  $i$  can be calculated as:

$$p_i = \frac{O_i}{\sum_{k \in L} O_k} \quad (7)$$

where:

$L$  is a set of loyal bees.

Using equation (7) and a random number generator, each uncommitted follower joins one recruiter through a roulette wheel.

#### 4. NUMERICAL RESULTS

The proposed algorithm is applied on a various test problems. In order to examine the effectiveness of BCO, the authors use Solomon's benchmark instances for the VRPTW. Parameters used for BCO implementation are the following:

- Number of iteration:  $IT = 1000$ ,
- Number of passes:  $NP = 20$ ,
- Number of changes in forward pass:  $NC=1$
- Number of bees:  $B = 60$  (20 of each type).

All instances are solved 10 times. The results are shown in the Table 1.

The first column of the Table 1 refers the name of the instance. The second column contains the best know result from literature [11]. Next two columns present the best results reached by the BCO algorithm, as well as relative error compared to the best known solution The last two columns show average solution obtained by 10 BCO runs and appropriate relative error.

As can be seen from Table 1. the BCO algorithm achieved results that differ from the best known in range from 0 to 6.19% depending on instance's difficulty. These results can be evaluated as satisfactory since this is the first attempt to apply BCO based on solution improvement to VRPTW. also, we didn't use any improvement algorithm such as 2-opt. all the tests were performed on Dell laptop with following characteristics: Intel core i5-2430m, 2.4 GHz, under Windows OS.

**Table 1. Obtained results**

Instance	Objective function value of the best known solution	BCO			
		The best obtained	Rel.Err. (%)	Average	Rel.Err (%)
R101	1642.88	1654.19	0.69	1664.21	1.30
R102	1472.62	1498.76	1.78	1517.32	3.04
R103	1213.62	1264.19	4.17	1293.96	6.62
R104	986.1	1006.2	2.04	1035.34	4.99
R105	1360.78	1389.02	2.08	1412.52	3.80
R106	1241.52	1281.17	3.19	1306.94	5.27
R107	1076.13	1119.7	4.05	1153.49	7.19
R108	948.57	975.922	2.88	1009.13	6.38
R109	1151.84	1199.35	4.12	1225.49	6.39
R110	1080.36	1147.27	6.19	1165.93	7.92
R111	1053.5	1112.42	5.59	1148.66	9.03
R112	953.63	987.804	3.58	1025.03	7.49
C101	828.94	828.937	0.00	828.94	0.00
C102	828.94	828.937	0.00	828.94	0.00
C103	828.06	852.19	2.91	866.53	4.65
C104	824.78	853.301	3.46	867.29	5.15
C105	828.94	828.937	0.00	828.94	0.00
C106	828.94	828.937	0.00	828.94	0.00
C107	828.94	828.937	0.00	828.94	0.00
C108	828.94	828.937	0.00	828.94	0.00
C109	828.94	833.696	0.57	844.82	1.92
RC101	1623.58	1654.94	1.93	1676.97	3.29
RC102	1466.84	1496.06	1.99	1523.25	3.85
RC103	1261.67	1301.27	3.14	1343.44	6.48
RC104	1135.48	1152.61	1.51	1179.30	3.86
RC105	1518.6	1554.93	2.39	1589.37	4.66
RC106	1377.35	1406.62	2.13	1430.54	3.86
RC107	1212.83	1236.74	1.97	1292.58	6.58
RC108	1117.53	1144.17	2.38	1168.21	4.53
Average			2.23		4.08

#### 5. CONCLUSION

The Bee Colony Optimization is meta-heuristic technique created by the analogy with foraging behavior of honeybees, realizing the concepts of collective intelligence. A population of artificial bees searches for the optimal solution with cooperation that enables more efficiency and allows bees to reach the goals they could not achieve individually.

In this paper the BCO heuristic algorithm is used to tackle the vehicle routing problem with time windows. Authors applied the improvement concept of BCO. The proposed BCO algorithm is tested on various benchmark examples. Based on the preliminary results, we can conclude that BCO is able to produce high quality solution for all tested well known benchmark examples.

The achieved results indicate that the development of new models based on swarm intelligence principles could considerably contribute to the solution of difficult logistic problems.

## ACKNOWLEDGMENT

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## THE AIRLINE BOARDING PROBLEM: SIMULATION BASED APPROACH FROM DIFFERENT PLAYERS' PERSPECTIVE

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***Abstract:** In order to sustain profitable growth, it is crucially important for both airports and airlines to revise possibilities to reduce turnaround time, as one of the most significant factor that highly influence total cost of airlines and efficiency of airports. Although boarding time as a part of turnaround time is not the major contributor of delay of an airplane, it is evident that has more opportunity to be altered compared to other components in turnaround time set. In this paper we developed a simulation model that investigates different boarding patterns, in order to detect the most efficient one, from different players' perspective, by taking into consideration mainly individual boarding times. The results are analyzed with regard to airline objectives as well as to customer objectives, and some of the implementation issues are also being considered.*

***Keywords:** Simulation, Boarding strategy, Airline boarding process, Transportation, Boarding times.*

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### 1. INTRODUCTION

Over the last few decades, the demand for air transportation has grown rapidly. Use of hub-and-spoke systems has been increasing, causing a high number of airplanes to arrive at the hub airports within a few hours. In order to avoid airport congestions, which can cause delays, but also to increase operational efficiency, airlines are continuously in a search for new ways to reduce turnaround time. By minimizing turnaround time airlines can increase aircraft utilization, which generates revenue. They do not generate any revenue while aircraft is on the ground. Thus, the reduction in airplane turnaround time is a crucial factor that has direct impact on reducing the costs of an airline. Airplane turnaround time is defined as "the time required to unload an airplane after its arrival at the gate and to prepare it for departure again". It consists of actions such as deplaning, cargo unloading and loading, fuelling, cabin cleaning, galley servicing and enplaning (boarding). Moreover, airline is solely involved in the process of boarding which allows creating the most efficient strategy itself. Compared to other components in turnaround process that are very straightforward, boarding component can be subject to modification

and alteration to a certain level. Furthermore, because of safety and operational constraints, passenger boarding is the last task performed in this timeline. In other words, any time saved through efficient boarding directly reduces the turnaround time. Consequently, airlines currently strive to achieve more effective boarding process pattern. In last decade, significant scientific and airline industry expert efforts have been dedicated to airline boarding issue. In addition to financial losses that can occur due to inefficient boarding process, it can also lead towards poor passengers' perception of airline service quality. Several strategies adopted by many airlines nowadays, especially those in United States, have been recently proposed by group of academics.

The leading work by Van Landeghem and Beuselinck emphasize the importance of revision of traditional boarding strategy used by many airlines [9]. The authors identified seven boarding models to include random, by block, by half-block, by row, by half-row, by seatgroup, and by seat. According to these authors, boarding times can be extended by interruptions that occur during seat interference, aisle interference or lack of overhead bin vacancies. Seat interference occurs when passenger's seat is closer to the window than another passenger nearer to the aisle in the same half-row already seated. In

that case, the seated passenger rise and move back into the aisle to allow the other passenger access to his seat. On the other hand, aisle interference occurs when one passenger is obstructed by another passenger who is stowing his luggage, seating himself, or obstructed himself. In such situation, the first passenger must wait behind the other passenger until removes himself from aisle or moved forward. The most time-consuming congestion component identified by Van Landeghem and Beuselinck was storing carry-on luggage. This type of delay occurs when a passenger needing to stow their luggage in overhead bins cannot do so because the overhead bins near his seat are full. Thus, the passenger must then move either upstream or downstream in an attempt to find a vacancy for his luggage. Final conclusion of these two authors reveals very strong correlation between total boarding time and average individual boarding time. In other words, the strategies applied yields the fastest individual boarding time and therefore higher level of passenger satisfaction. Reverse pyramid is boarding strategy that was initially developed by Van den Briel et al. in order to reduce boarding time in American West Airlines [8]. Reverse pyramid strategy calls for simultaneously loading an airplane from back to front and outside-in – window and middle passengers near the back of the plane board first and those with aisle seats near the front are called last. Relying on the previous work by Van Landeghem and Beuselinck, Ferrari and Nagel define the model that calculates time associated with storing carry-on luggage as a function of the number of bags already in the bin plus the number of bags being carried by each passenger [4]. The model fails to account aisle interference that occurs once a bin has reached capacity and passenger must move along the plane in search of open bin space. Bazargan introduces a new mixed integer linear program to minimize the total number of passenger interferences [2]. The recommended efficient solutions are more appealing to both airlines and passengers as they can accommodate neighboring passengers to board together. Bachmat and Elkin provide bounds on the performance of back-to-front policy can be more than 20% better than the policy which boards passengers randomly [1]. Steffen finds the passenger ordering that minimized the time required to board an airplane by employing Markov Chain Monte Carlo optimization algorithm [6]. The entire idea of an optimized boarding strategy focuses on spreading the passengers who are loading their luggage throughout the length of the airplane instead of concentrating them in a particular portion of the cabin. Tang et al. develop a new aircraft boarding

model with consideration of passengers' individual properties and then design three different aircraft strategies and used proposed model to explore the aircraft boarding behavior under the three aircraft boarding strategies [7].

Boarding process was comprehensively examined by world leading aircraft manufacturer – *Boeing*. Boeing began using discrete event simulation to understand interactions in the factory environment. In 1994, Boeing started applying the discrete event model in passenger boarding studies. PEDS (*Passengers Enplane/Deplane Simulation*) assigns each passenger certain attributes, such as walking speed, type of carry-on luggage, luggage put-away time, and relationship with other passengers (traveling alone or with a group) [3]. The simulation accounts for random behavior by applying probability distributions to passenger attributes.

Strategies adopted by mainly U.S carriers are presented in Table 1 [5].

**Table 1. Boarding strategy used by airline**

Boarding Strategy	Airline
Outside in	United
Random	Southwest, US Airways
Back to Front	Air Canada, Alaska, American, British Airways, Continental, Frontier, JetBlue, Spirit, Virgin, Atlantic
Reverse pyramid	US Airways (America West)
Rotating zone	AirTran
Zone/Block Style	Delta

As it is shown in Table 1. many airlines including Continental, American and JetBlue board back to front. Furthermore, United refers to their outside-in boarding process as *Wilma* (Window, Middle, Aisle). This outside-in system boards all window passengers first, followed by those with middle seats and finally, those seated in the aisle. Southwest does not assign seats, while US Airways has relatively random seating, though the airline does give preference to certain passengers, including elites and those who check in online. AirTran Airways launched a boarding system named as a rotating zone system. AirTran first seats the five back rows of the plane, then the front five, and continues rotating back-front-back until boarding is complete. By employing this strategy, AirTran reduce

turnaround times in the 20 to 30 minute range. Delta groups passengers into as many as nine zones which have different order of priorities.

In this paper we developed simulation model for a single aisle airplane. This model takes into account both airline and passenger's boarding time, that is the main contribution of this paper.

## 2. BOARDING PROCESS

Generally, the actual boarding process consists of the following three steps:

- 1) Passengers are called to boarding by gate agent. If certain strategy is applied, they are called to board in exact sequence. At this time passengers start queuing at the gate, while gate agent controls the boarding pass of each passenger.
- 2) Passengers resume their movement towards the airplane, usually through the access bridge, but in some cases they might be transferred to the airplane by bus.
- 3) Finally when passengers access the airplane, they yet again form a queue, within single aisle airplane until they reach their seats. Within the airplane, several interferences and delays may occur as a result of passengers' behavior, which we detail below. When they reach their row, passengers need to stow their luggage in the overhead bin compartment, but they also block the aisle while doing so. After completion of such action, unless there are no seat interferences, passenger can finally sit. Otherwise passenger that blocks the way has to get up from his seat and let him pass.

## 3. COMMON STRATEGIES

Call-off-systems, also named boarding strategies, are of crucial importance in controlling the flow of passengers onto the aircraft. In our observations we found that various airlines impose different boarding strategies, based on airline culture and service level. Our model investigated only 3 strategies, Back to Front (BF), Random (RDM) and Out-in (OI) boarding strategy. These three were selected as fundamentally different, while the others can be subsumed under, as a variation or a combination of these categories.

Back-to-front (BF) boarding strategy, is the most common boarding technique. It divides passengers into groups, which are then called to board the airplane in sequence, starting from back of the airplane towards front, as the name implies.

In random (RDM) boarding strategy, no specific strategy is used. All passengers belong to a single boarding group, and they enter into the airplane randomly. This boarding process is often used as a baseline for comparison to other models.

Out-in (OI) boarding strategy, also called window-middle-aisle boarding strategy, divides passengers into three groups. As the name implies, passengers who are seating in window seats boards first, than middle seat passengers, and finally in the third group are those passengers who seat in the aisle seats. In previous research it was found that OI strategy was among the most efficient boarding strategies.

## 4. SIMULATION MODEL

We focused our study to Short Haul flights, which typically use airplanes with seating capacity between 80 and 150. We modeled airplane with 120 seats, divided into ( $n=20$ ) rows. Influence of First class, frequent flyer and passengers with disabilities, who in practice always boards first, was disregarded in this model.

In this paper, we simulated only the movement of passengers inside the aircraft, which basically means that Steps 1 and 2 of boarding process were disregarded. Yet, since the stream of passengers that enters the airplane doors depends on gating operations (the rate at which gate agent checks boarding passes), we simulated this action as well. The model assumes passengers arrive at the airplane at the rate that is normally distributed around mean  $\mu=5$  seconds, ( $\sigma=2$  seconds). Each passenger was randomly assigned to a seat on the plane, but randomization was adapted according to strategy in use. Passenger movement throughout the aisle was simulated by time it takes them to pass 1 row of seats, for which, triangular distribution (Min=1.8 seconds, Mode=2.4 seconds, Max=3 seconds) was used. Passenger movement depends on various interferences. It also depends on their interactions with other passengers, which means that the passenger will move forward only if the next row is clear.

Seat interferences in the model occur as a consequence of randomized sequence in which the passengers board the aircraft. The time needed to resolve such a conflict was simulated with triangular distribution (Min=3 seconds, Mode=3.6 seconds, Max=4.2 seconds). Seat interferences may also cause aisle interferences, as they usually do.

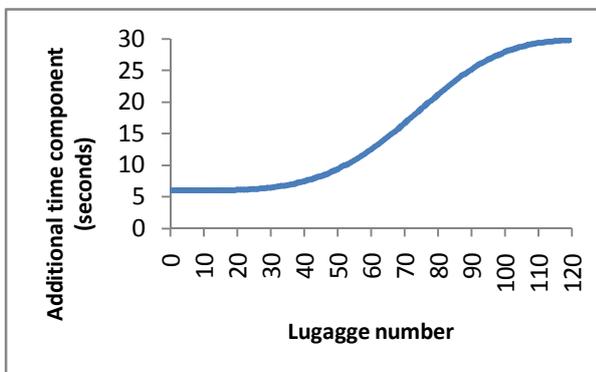
Aisle interferences can occur during an action in which passengers stow their luggage, as well. Duration of this action depends on the number of

carry-on luggage involved and this model assumed that 25% of all passengers carry-on 2 bags, 50% carry-on 1 bag, while 25% does not carry-on any bag at all.

The model calculated the time factor, associated with storing carry-on luggage by evaluating the number of bags already in the bin. Calculated time factor ( $T$ ) is then multiplied by the number of carry-on bags being carried by each passenger. To determine values of time factor ( $T$ ), associated with storing carry-on luggage, we used Weibull cumulative ( $k=4$ ,  $\lambda=80$ ) distribution function as a measure of additional time it takes to load luggage as the plane fills up. We considered this distribution as the most appropriate among many others which are currently used in the literature since it takes into account the main features of storing luggage process in overhead bins. The expression for the calculated time factor ( $T$ ) for passenger, who carries  $x$ -th bag into the airplane, is calculated with the equation (1),

$$T = c * F(x, k, \lambda) + n \quad (1)$$

where  $c$ - (24 seconds) is a measure of the additional time we would expect someone to take to store baggage when the overhead bin is full,  $F(x, k, \lambda)$  is the Weibull cumulative distribution function and  $n$ - (6 seconds) is a minimal time required to store the luggage.



**Figure 1. Cumulative distribution function of a Weibull distribution**

As Figure 1 shows, obtained function has sigmoid shape, consistent with our baggage loading process. When there are few bags in the airplane, time required to load the luggage is relatively small (around 6 seconds). As the number of bags increases, this time increases slowly when there is still a lot of space and then rapidly as people start having to rearrange compartments to fit their luggage. When overhead compartment reaches its full capacity, the difference in time required to find space for baggage becomes minimal as most baggage bins have relatively little space left.

In order to review effectiveness of various strategies from different perspectives, we developed simulation model that simulates passenger boarding process. The boarding procedure has been simulated and analyzed using GPSSH simulation software. Simulation model that we proposed consists of several consecutive steps:

- Start – in this block, the stream of passengers that have been generated,
- Assignment of input parameters – number of seats, passenger movement, time for storing carry-on luggage, group of passengers, time for storing carry-on luggage in the case of seat interference,
- Time measuring block,
- Assignment of the row to each passenger who enters the system – the purpose of this block is to simulate movement of passenger through the plane,
- Assignment of the seat to each passenger,
- Print the output results,
- End.

## 5. RESULTS

Our main goal has been divided into two sections. First task was to determine the most efficient strategy from airlines perspective. Second goal was to determine the most efficient boarding strategy from passengers' perspective.

Total boarding time is clearly important from airlines perspective, since it determines the airplane turnaround time. Therefore we analyzed the total boarding times for, above mentioned, scenarios. The results that represent the average from 20 realizations are shown in Figure 2. In each realization, for every passenger, personal characteristics, such as their seat number, speed, luggage loading time, and time to resolve seat interferences, were randomly altered.

As shown in Figure 2, in regard to total boarding time, BF strategy performed worst with an average of  $\mu=24.61$  minutes. RDM strategy performed very well with  $\mu=19.02$  minutes in average, while OI was shown as the best, as it lasted  $\mu=17.51$  minutes in average.

We also measured standard deviation which showed that data from BF strategy is widely spread, making this strategy less reliable ( $\sigma=2.72$  minutes), than the other two. Value of standard deviation for RDM strategy were clustered closely around the mean  $\sigma=1.90$  minutes, while results for OI strategy performed even better, because they tend to be even closer to the mean ( $\sigma=1.78$  minutes).

Better results of RDM strategy versus BF strategy can be explained by the fact that RDM strategy uses the aisle space more efficiently since more passengers who enter the airplane can put their luggage in parallel. In this manner the aisle is not used as a passive extension of the waiting area, but rather as a place for passengers to actively situate themselves. On the other hand in BF strategy only the first few would be putting their luggage away while the others have to wait their turn, meaning that passengers would load their luggage serially. By doing so, BF strategies prolong the passenger boarding process. In OI strategy, passengers can also put away their luggage in parallel as the RDM strategy, but it also eliminates all seat collisions from the boarding process, and by doing so it performs even better than the RDM strategy.

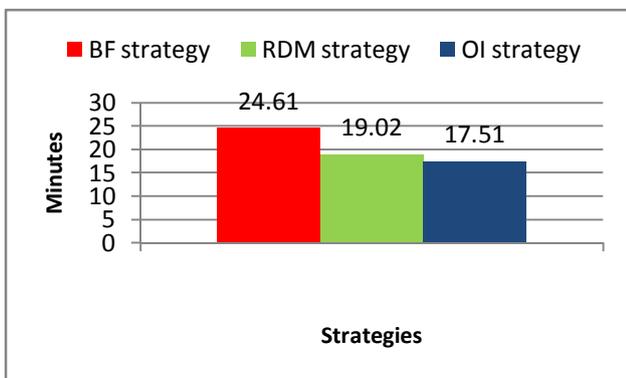


Figure 2. Total boarding times, for different strategies

However passengers are more susceptible to the waiting times they experience personally. Therefore, we also examined individual boarding times for each passenger from 20 realizations.

Our founding was implying that very high correlation between total boarding time and average individual boarding time exists, as could be expected. It means that strategies which performed really badly when it comes to total boarding times, such as BF strategy, also generate long individual boarding times. In our model, for example, individual boarding time, via BF strategy, lasts in average  $\mu=4.59$  minutes, per passenger with standard deviation  $\sigma=4.15$  minutes. We also noted that RDM strategy performed surprisingly better than BF strategy with individual average time  $\mu=2.74$  minutes, and standard deviation  $\sigma=2.44$  minutes. Fastest method (OI strategy), as could be expected, also yields the best passenger comfort since it generates lowest average  $\mu=2.29$  with standard deviation  $\sigma=2.00$  minutes.

Since the average values alone, didn't provide us with enough information about boarding process from passenger's perspective, we further analyzed

results. More detailed information on individual boarding times for each strategy is displayed in Figures 2, 3 and 4.

In order to present our founding's more clearly, we introduced certain assumptions into our analysis. We assumed that passenger would be satisfied if they board the airplane within 4 minutes. On the other hand if individual boarding lasts more than 10 minutes, it is considered as unacceptable, since it reduces, in great deal passengers' perception on service quality.

If airline chooses to implement BF strategy, nearly 60% of its passengers would board the airplane within 4 minutes, while 14% of them would be unsatisfied since they need more than 10 minutes to reach their seats. Figure 3 illustrates distribution of individual boarding times in percentage.

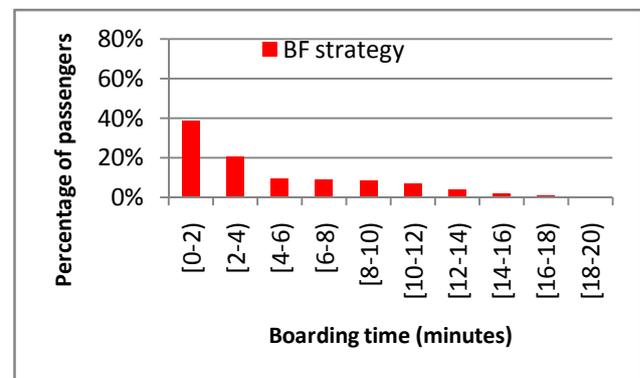


Figure 3. Relative frequency distribution of individual boarding times for BF strategy

With RDM strategy, around 74% of its passengers would board the airplane within 4 minutes, and the percentage of passengers that falls into "unsatisfied" category is slightly above 1% as it can be seen in Figure 4.

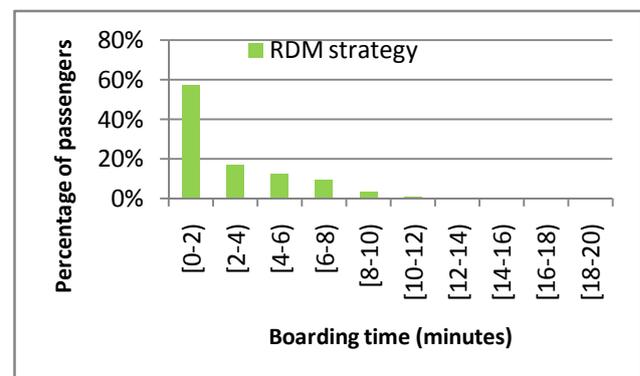


Figure 4. Relative frequency distribution of individual boarding times for RDM strategy

Greatest passenger satisfaction can be achieved with OI strategy (Figure 5). Around 81% of passengers can reach its seats within 4 minutes,

while the number of “unsatisfied” passengers is negligible.

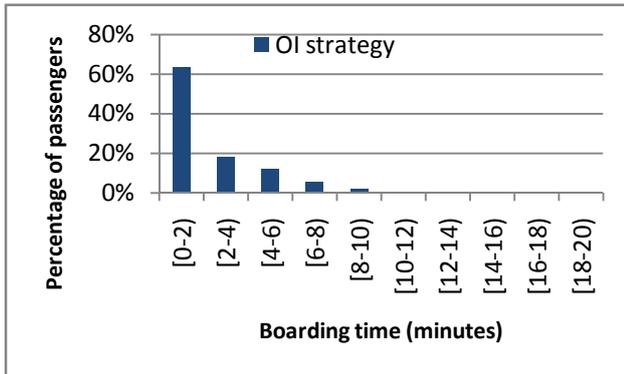


Figure 5. Relative frequency distribution of individual boarding times for OI strategy

## 6. CONCLUSION

In this paper three different boarding patterns have been examined in order to investigate their efficiency from both airlines and passengers' perspective. For that purpose, new simulation model of boarding process was developed. Total boarding times were measured as metric of efficiency from airlines perspective, while individual boarding times represented boarding efficiency from passengers' perspective.

Findings indicate that there is a strong correlation between total and individual boarding times as could be expected. Nevertheless, study showed that by investigating individual boarding times one can get better insight into the overall boarding process. In other words they need to be included into analysis in order to gain more detailed information about the effects that any change has on a boarding process.

Surprisingly, study showed that RDM strategy is far more effective than BF strategy commonly used by many airlines around the globe. In addition to that RDM strategy is much easier to implement, since no regulation of process is needed. Although OI strategy outperformed the other two in each aspect, its implementation issues might be an obstacle which cannot be surpassed. Separation of passengers who are traveling together, during the

boarding process, for example might be unacceptable for many of them.

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## TIME BETWEEN AIRCRAFT OVERHAULS OPTIMIZATION BY MAXIMIZING FLEET TOTAL FLYING HOURS

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***Abstract:** The purpose of the work was to investigate the feasibility of determining when an aircraft should be overhauled in order to maximize the total flying hours of a fleet. It was assumed that the aircraft reliability parameters are known. Also, it was assumed that maintenance capacity is limited and constant. Analysis was based on a discrete-event simulation model using General Purpose Simulation System (GPSS), which estimates available and achieved flight hours of a military aircraft G-4 fleet throughout complete life cycle, under a certain maintenance scenario. The model also gives all necessary parameters to compute the total aircraft maintenance cost, linking reliability, operational tempo and maintenance scenario.*

***Keywords:** aircraft, overhaul, simulation, optimization.*

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### 1. INTRODUCTION

The Integrated Logistic Support (ILS) is the process that facilitates development and integration of all of the logistics support elements to acquire, test, field, and support military systems. The ILS elements are: maintenance, manpower and personnel, supply support, support equipment, technical data, training and training support, computer resources support, facilities, packaging, handling, storage, and transportation, and participation in complete engineering process of a system [1]. Objective of the maintenance planning is to identify, plan, provide resources, implement maintenance concepts and requirements, and to ensure the best possible equipment/capability available, when a military unit needs it at the lowest possible cost.

Aircraft, as a military system, need to be maintained for many different reasons. To have a high safety and reduced costs, are two reasons. Both corrective and preventive maintenance are carried out on aircrafts. The preventive maintenance cost a lot of money and during the maintenance time, the aircraft is not available for flying. One major part of the aircraft preventive maintenance is to undertake

overhauls. The overhauls are flight time dependent and need to be carried out before the aircraft are allowed to fly again. During the overhaul, there are often a lot of other maintenance tasks carried out like repairs and modifications. A good plan for the required maintenance capacity in the workshops is essential to reduce the total maintenance cost. There is also another reason to have the right maintenance capacity and schedule, that is - the availability of the fleet needs to be high enough. If the workshop capacity is too low, it will lead to a low availability of the aircrafts and that can lead to problems of achieving the targeted flight time production. One part in determining the total maintenance needs is to determine the optimal overhaul capacity.

However, there are situations in practice with a developed and fixed maintenance capacity, limited available flight hours, and an increased operational tempo needs. In this work the optimization model has been formulated as flight hours maximization under limited overhaul capacity, changing aircraft maintenance scheduling, the overhaul extent and available flight hours after the overhaul. To be able to construct the model, the maintenance work at the Serbian Air Force has been studied. The parameters that are needed for the model have been described.

Verification of the model has been carried out through G-4 fleet (30 aircraft) example.

## 2. RELATED WORK

The development of life-cycle models is necessary to identify key factors that affect operational readiness and cost of required readiness. Modeling needs complex and time consuming research to examine many input parameters and possible scenarios, and models usually cover specific system or only a part of a life-cycle.

One approach uses optimizations maximizing availability and profitability of the production system by varying both maintenance strategies and logistics factors. The obtained results indicate that a joint optimization of logistics and maintenance strategies provides better results than optimizing those elements independently and highlights the need for a comprehensive sophisticated model [2]. Another approach combines knowledge from government and industry space operation and design experts, with system analysis methodologies to predict operational characteristics of a future space transportation system. The model proposed under this approach utilizes expert knowledge to predict the operational requirements of a system, incorporates simulation in order to include alternatives, processing variability, and other random events [3]. Some researches combine several models that can be used in identifying critical logistics factors that have an impact on the system readiness and life cycle cost. Typical concept uses two models: the first one, a discrete-event simulation model, estimates the operational availability of a system given input parameters under a certain scenario. The second one, a spreadsheet model, computes the life cycle cost using the same input parameters for the simulation model [4]. One method provides a complete formulation for maintenance scheduling and a heuristic approach to solve the problem. The heuristic procedure provides good solutions in reasonable computation time [5]. Some works deal with specific maintenance facilities. One paper presents an approach to determine the optimal aircraft overhaul capacity in the workshops for JAS 39 aircraft fleet. The aircraft fleet contains one aircraft type with different models of that type. A mathematical model has been constructed to calculate the lowest cost alternative. The mathematical model uses various types of data to calculate the optimal workshop overhaul capacity like costs, times, numbers of workers, aircrafts used flight time etc. [6].

In this work an integration of available flight hours and maintenance optimization is done, based on vehicle life cycle simulation. The simulation model is a very flexible one and gives the opportunity to change a variety of parameters: fleet size, aircraft reliability, operational tempo, work allocation between maintenance levels, time-to-repair distribution, preventive maintenance strategy, etc. The model is also applicable to other maintenance systems [7]. The simulation results give a detailed insight into fleet life cycle: obtained flight hours of the fleet and every aircraft, maintenance facilities utilization, queues, logistics administrative time, maintenance labor, maintenance cost (minimal, maximal, mean, standard deviation).

## 3. AIRCRAFT MAINTENANCE SIMULATION MODEL

The simulation model was built using GPSS in such a way that software not only provides tools for modeling and simulation of a wide variety to maintenance services, but also has possibility to shape input data and carry out output statistics [8]. Simulation model describes a traditional three-level maintenance concept, consisting of Organisational level (OLM), Intermediate level (ILM) and Depot level (DLM) maintenance adopted for aircraft G-4.

The OLM is performed by operational squadron and consists of the preparation of aircraft for flight and elementary aircraft servicing, including these activities: pre-flight inspection, thru-flight inspection, post-flight inspection, aircraft servicing and operation, aircraft ground handling, ammunition loading, and remove/replace of failed line replacement units (LRUs).

The ILM is performed by maintenance squadron and consists of work on the aircraft as well as on individual disassembled components. During the ILM, activities defined within both, the scheduled and unscheduled maintenance, are carried out. Scheduled Maintenance consists of periodic and phase inspection activities carried out on mechanical systems such as: airframe systems servicing, clearance check and adjustment, cleaning or replacement of the filter elements, lubricating according to lubrication plan. In the course of aircraft operation, unscheduled maintenance activities occur, too. These are especially: special inspection after a specific occurrence, upgrades or maintenance activities performed on aircraft systems in compliance with bulletins, remove/replace of systems components due to failure, troubleshooting and isolation. The OLM and ILM are performed within squadrons at one Air Force Base.

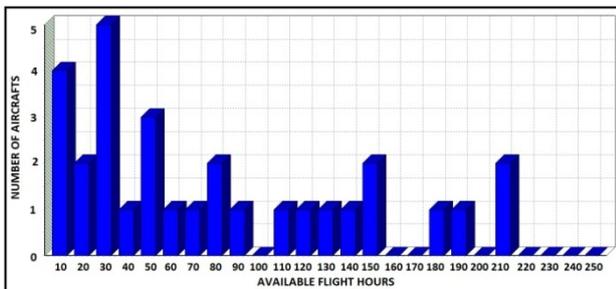
Detailed specification of the Depot level maintenance performed on each system, aggregate and module are based on the logistic support analysis. The period of Depot level scheduled maintenance depends of aircraft design and technology and for G-4 aircraft is designed to every 1,000 flight hours.

Scheduled maintenance mostly covers airframe and mechanical systems and consists of: (1) phase inspections after 50, 100, 200 flight hours, (2) periodic inspections based on calendar time, cycles, starts, and landings.

Output parameters of the model are: fleet availability, aircraft availability, fleet flight hours, aircraft flight hours, aircraft usage histogram, number of preventive maintenance actions, aircraft preventive maintenance histogram, number of corrective actions, maintenance capacity utilization, queues, total preventive maintenance working hours, total corrective maintenance working hours, aircraft failure histogram, ect.

**4. EXAMPLE**

The importance of simulation and its use in optimization lies in the fact that many problems are too complex to be described in mathematical formulations. Nonlinearities, combinatorial relationships or uncertainties often give rise to simulation as the only possible approach to solution. Our simulation model is tested through relatively complex example: find the most effective (maximum flight hours) overhaul concept under financial and maintenance capacity constraints, for a fleet of 30 aircrafts. The optimization process consists of four steps: (1) Requirements establishment, (2) Definition of maintenance alternatives, (3) Fleet life cycle simulation for every maintenance alternative, and (4) Selection of the optimal solution.



**Figure 1. Aircraft available flight hours histogram**

*Requirements* – Optimize aircraft maintenance system for G-4 fleet (30 aircrafts), adjusting time between overhaul. The optimization aim is maximization of available flight hours for 5

operational years. The maintenance capacity consists of 20 OIL teams, 5 working places and teams for ILM, and 4 working places and teams for DLM. Average operational tempo needs 300 flight hours per aircraft per year. Starting available flight hours are 5780 (173 hours per aircraft), and their distribution per aircrafts is shown in Figure 1. G-4 service life is 5000 flight hours.

*Maintenance alternatives* – For the illustrative purpose two DLM alternatives are simulated. Alternative 1 is the basic, shown in Table1. Every time the G-4 aircraft reaches 1000 flight hours, the aircraft is taken out of service for overhaul. Meaning that, it will undergo overhaul after 1000, 2000, 3000 flight hours, and so on. The first overhaul is called TO1 and the second overhaul is called TO2 and so on.

**Table 1. G-4 basic overhaul schedule**

<b>G-4 Overhaul Alternative 1</b>	
Name	Flight Hours
TO1	1000
TO2	1000
TO3	1000
TO4	1000
TO5	1000

Alternative 2 is called short overhaul, because time between overhauls is shortened, overhaul activities are reduced, and aircraft gets less available flight hours after every implemented overhaul. This alternative is the most cost effective among a set of short overhauls, and it is shown in Table 2.

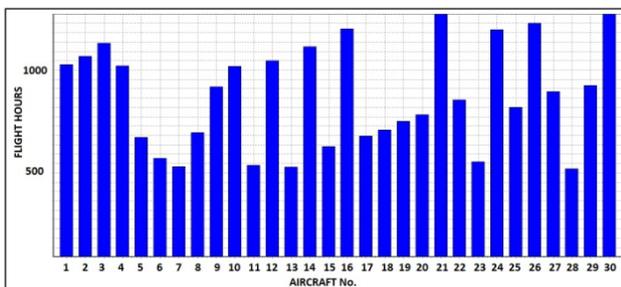
**Table 2. G-4 short overhaul schedule**

<b>G-4 Overhaul Alternative 2</b>	
Name	Flight Hours
SO1	500
SO2	500 1000
SO3	500 1500
SO4	500 1000 2000
SO5	500 1500 2500
SO6	500 1000 2000 3000
SO7	500 1500 2500 3500
SO8	500 1000 2000 3000 4000
SO9	500 1500 2500 3500 4500
SO10	500 1000 2000 3000 4000 5000

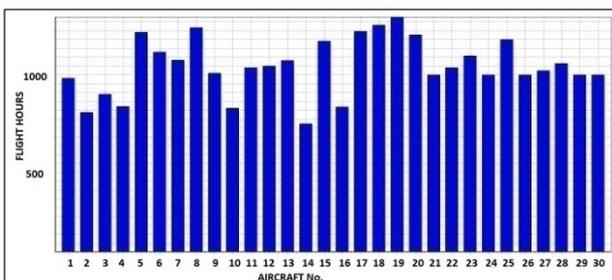
In this alternative aircraft will undergo overhaul after 500 FH, 1000, 1500 flight hours and so on. The first overhaul is called SO1 and the second overhaul is called SO2 and so on. There are different maintenance tasks to be done depending on how much the aircraft have flown. The first time an aircraft come for overhaul the maintenance tasks are carried out every 500 flight hours that means in other words that this maintenance tasks will be carried out every time the aircraft undergo overhaul. The second time the aircraft come in for overhaul, besides the maintenance tasks of every 500 flight hours, the maintenance tasks for every 1000 flight

hours are also carried out. The third time the aircraft is undergoing overhaul, the maintenance tasks at every 500 and 1500 flight hours are carried out. Between overhauls, flight time dependent services are carried out. The services are done at the flying units on their maintenance department, can be also carried out at workshops, if necessary. There are also services that are not flight time dependent and that is the service that are done before and after every flight.

*Simulation* - Objective functions are the target functions in focus on which the optimization criteria are deployed, either minimizing or maximizing the objective function by varying the decision variables. The objective in our example is the maximization of the fleet flight hours with fixed maintenance capacity. Optimization process consists of repetitive simulation runs with different values of the influence variables. Those variables are varied from simulation to simulation to find optimal combination of parameter values to solve the problem with respect to the objective function and constraints. Influence variable are aircraft operational tempo and maintenance alternatives. Results for one operational tempo and two overhaul alternatives are shown in Figure 2 and Figure 3.



**Figure 2. G-4 fleet flight hours during 5 years of service, overhaul alternative 1**



**Figure 3. G-4 fleet flight hours during 5 years of service, overhaul alternative 2**

Results show that for the simulated operational tempo overhaul alternative 2 gives more flight hours (average 1051 flight hour per aircraft, standard deviation 157 flight hours), then overhaul alternative

1 (average 859 flight hour per aircraft, standard deviation 275 flight hours).

*Optimal solution* – Simulation runs for all operational tempos have shown that overhaul alternative 2 provides more G-4 fleet flight hours than alternative 1. The simulation results are reasonable, because short overhauls allows better aircraft availability. But, there are many parameters that affect the overhauls. The values of the parameters are important to be reliable so the result from the model also can be reliable.

## 5. CONCLUSION

Results of the simulation runs confirmed the assumption that aircraft availability can be improved by optimizing a maintenance strategy, with fixed maintenance capacity. Our simulation model is flexible enough to cover variety of scenarios: different requirements, different fleet size, different aircrafts, different operational tempos, different maintenance strategies and infrastructure, etc. The model functionality was demonstrated through an illustrative example of 30 F-4 aircraft fleet.

## ACKNOWLEDGMENT

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## TWO-STAGE AIRLINE FLEET PLANNING MODEL

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**Abstract:** Fleet planning is a process of strategic importance for an airline. Airlines have a tendency to match their capacities and passenger demand for corresponding market conditions, which has a direct impact on airline profitability and costs. It is necessary to consider many different factors in order to make a good fleet plan. This paper proposes the sequential two-stage model for fleet planning. The first stage refers to determination of an approximate fleet mix in terms of aircraft size which is obtained by fuzzy logic. The outputs from this stage are two sets of routes: one presenting routes covered by small aircraft and another one presenting routes covered by medium size aircraft. At the same time, these outputs represent inputs for the second stage in which the fleet sizing problem is solved using heuristic procedure. The sequential two-stage model is exemplified with the incumbent airline with its base at Belgrade Airport.

**Keywords:** airline fleet planning, fleet mix, fleet sizing, fuzzy logic.

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### 1. INTRODUCTION AND LITERATURE REVIEW

One of the main goals of an airline is to match its capacity and passenger demand for corresponding market conditions, which has a direct impact on the increase of airline profitability and reduction of airline costs. Since acquisition of a new aircraft requires a huge investment, it is evident that a small savings of a few percent, is not negligible for an airline. In order to achieve even such a small savings, adoption of an appropriate methodological approach is essential.

Generally, fleet planning process is very complex for an airline. It is necessary to consider many different factors, such as aircraft economies, commonality, aircraft performances, finance, market evaluation, etc. With regard to time perspectives in fleet planning, it is obvious that the market and environment in which an airline operates are predictable for a relatively short time and uncertainty increases with time. Strategic planning is fundamental to overcome the gap between the growing flexibility of resources and growing uncertainty of the market.

Many authors have dealt with the fleet planning problem in different ways. Most of them research the close connection between airline frequencies and aircraft size considering more or less similar factors. The factors that have influence on airline flight

frequencies and aircraft size on US airline routes taking into consideration market demographics, airport characteristics, airline characteristics and route characteristics are commented in [8]. Regression analysis is used [2] to point out that route characteristics, such as distance, level of demand and competition, strongly influence the selection of aircraft size, while airport characteristics (number of runways, hub or not hub) do not influence aircraft selection. A nested logit model is developed [10] in order to investigate influence of aircraft size, frequencies, seat availability and fare in airlines' demand and market share in duopoly markets. They demonstrate that an airline achieves greater market share by increasing frequencies rather than increasing seat availability per flight. The paper [7] focuses on operating effects of leasing rather than financial effects. It indicates that an airline which needs additional capacity in short time period may not reach advantageous agreements with manufacturers (higher prices and waiting for delivery), while large leasing company can provide aircraft from manufacturers in shorter time period and at lower prices. They can lease aircraft from a leasing company in order to adjust the airline's capacity and demand. Dynamic programming in decision-making process related to the number of aircraft to be bought, leased and retired is proposed in [4]. [3] indicates the environmental implications with regards to airlines' selection of aircraft size.

They mention the importance of frequency for preserving the airline position on the market and the fact that airlines prefer increasing frequency to increasing aircraft capacity, especially on short routes. It can be observed that the baseline in most of the papers written on this topic is travel demand.

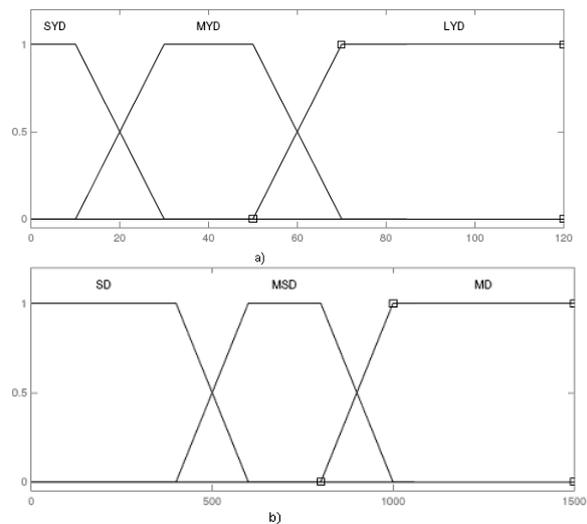
In this paper, the authors try to help planners by proposing a sequential, two-stage model which could be used during the airline fleet planning process. The output of the first stage is the input for the second one. The model should offer a solution for an assumed route network – an approximate fleet mix from the first stage and fleet size from the second stage, which fit the market conditions and airline requirements. Passenger demand and distance are the inputs to the first stage in order to get approximate fleet mix in terms of aircraft size. Small or medium-size aircraft are assigned to each destination according to the index of preference obtained from fuzzy logic system. The outputs are two sets of routes: one set presents the routes covered by small aircraft and the other one presents routes covered by medium-size aircraft. The number of small and medium aircraft depends on weekly frequencies and airline schedule. With splitting the set of planned flights into subsets, the problem transforms into two independent fleet sizing problems. The solution to these problems obtained by heuristic procedure should answer the following question: How many small and medium aircraft does the airline need in order to implement the planned flight schedule?

Models developed are exemplified by the incumbent airline with its base at Belgrade Airport which should replace existing one on the established market. The paper has 4 sections. After the introduction and literature review, the first stage of the sequential model for approximate fleet mix determination is presented (Section 2). The third section presents the heuristic procedure for fleet sizing problem. The last section gives concluding remarks and further research directions.

## 2. MODEL FOR APPROXIMATE FLEET MIX

The main assumption in the model for approximate fleet mix determination is that all aircraft can be classified into two categories – small and medium size aircraft. A small aircraft is an aircraft with capacity of 50 to 100 seats, while a medium size aircraft has the capacity of 101 to 200 seats. Each of these categories comprises different types of aircraft which differ in capacity, technical characteristics, dimensions, noise generation level, take-off or landing runway length. Taking into

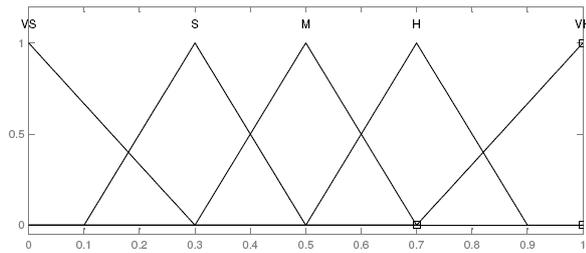
consideration passenger demand on selected routes and distance between origin and destination airport, a fuzzy system is created in order to help an airline planner to make a decision whether to use small or medium size aircraft. Based on the past experience, it has been decided to use trapezoid fuzzy sets as follows. The membership functions of fuzzy sets *Small* (SYD), *Medium* (MYD) and *Large* (LYD) are related to yearly demand (Fig. 1a), while the membership functions of fuzzy sets *Short* (SD), *Medium Short* (MSD) and *Medium* (MD) are related to distance (Fig. 1b).



**Figure 1. Membership functions of fuzzy sets**  
**(a) Small, Medium and Large yearly demand;**  
**(b) Short, Medium Short and Medium distance**

When selecting an aircraft for a given route, an airline has a certain preference for selection of the aircraft that will operate; therefore, strength of preference may be "stronger" or "weaker". Let us denote with  $p_s$  the index of preferences for using small aircraft and with  $p_m$  the index of preferences for using medium aircraft. Their values can range from 0 to 1, and their sum is always equal to 1.

Bearing in mind that sum of those indexes is 1, in following text, only the index of preference for operating small aircraft ( $p_s$ ) will be used. The value of  $p_s$  is equal to 1 when an airline has an absolute preference for using small aircraft on the considered route. The value of the  $p_s$  decreases with the decrease of airline's strength of preference, so the airline will use medium aircraft in cases when  $p_s$  is equal to 0. Airline's strength of preference for operating small aircraft may be described by using triangle fuzzy sets *Very Small* (VS), *Small* (S), *Medium* (M), *High* (H) and *Very High* (VH) strength of preference (Fig. 2).



**Figure 2. Membership function of fuzzy sets Very Small, Small, Medium, High and Very High strength of preference**

Index of preference for operating small aircraft is calculated on the basis of historical data used on selected routes. Data are taken from the Belgrade Airport's timetables for the period winter 2001 to winter 2012. Estimated index of preference ( $p_{se}$ ) represents the ratio between the number of small aircraft used and the total number of aircraft used on the considered route in the selected period, and its value, as aforementioned, varies from 0 to 1. The lowest value of  $p_{se}$ , equal to 0, means that small aircraft have never been used on the considered route, while the highest value 1 indicates that small aircraft are always used. Values of  $p_{se}$  for all destinations in the airline network assumed (consisting of 27 routes) are given in Table 1. It should be noticed that the network presents network defined in [5] and [6] extended to some new routes. Fuzzy rule base to determine the strength of preference consists of 9 rules.

For known yearly demand and distance between origin and destination airports, strength of preference for operating small aircraft can be determined for all routes by using the approximate reasoning rule base. The indexes of preference for operating small aircraft ( $p_{sf}$ ) are obtained by applying MAX-MIN fuzzy reasoning and defuzzification by centre of gravity.

Strength of preference to use small aircraft by applying fuzzy logic will not be determined for all destinations. Sometimes, it is known in advance. For example, if an airline is a new one on the market, it is evident that small aircraft will be in service for the beginning. If an existing airline introduces a new route, small aircraft will operate it due to the uncertainty of demand. When the value of  $p_{se}$  is not greater than 0.05, the route will be operated by medium aircraft, while small aircraft will operate the route for which the value of  $p_{se}$  is not smaller than 0.95. These cases will not be considered in the fuzzy logic system starting with these assumptions. Routes from Belgrade to Thessalonica and Ljubljana will be excluded from further consideration ( $p_{se} = 1$ ) and small aircraft will be assigned to them, routes to Paris ( $p_{se} = 0.02$ ), Amsterdam, Stockholm,

Gothenburg, London, Moscow and Monastir ( $p_{se} = 0$ ) will not be considered and medium size aircraft will operate these routes. Thus, there are 19 routes for  $p_{sf}$  determination by fuzzy logic system. Comparative review of  $p_{se}$  and  $p_{sf}$  for 2012 and 2015 is given in Table 1, as well as relative errors.

**Table 1. Index of preference (estimated and obtained by fuzzy logic) and relative errors**

Destination	$p_{se}$	$p_{sf}$		Relative errors	
		2012	2015	2012	2015
Vienna	0.66	0.64	0.55	0.04	0.17
Brussels	0.07	0.10	0.10	0.38	0.38
Copenhagen	0.07	0.10	0.11	0.43	0.56
Athens	0.53	0.28	0.28	0.46	0.47
Rome	0.22	0.30	0.30	0.36	0.36
Milan	0.38	0.43	0.43	0.12	0.12
Munich	0.48	0.47	0.36	0.01	0.24
Frankfurt	0.12	0.11	0.10	0.08	0.19
Stuttgart	0.43	0.34	0.35	0.21	0.20
Düsseldorf	0.27	0.10	0.10	0.64	0.63
Berlin	0.08	0.11	0.12	0.38	0.45
Prague	0.32	0.70	0.64	1.19	0.99
Skopje	0.61	0.79	0.53	0.30	0.14
Zurich	0.19	0.17	0.17	0.09	0.09
Sarajevo	0.91	0.90	0.90	0.01	0.01
Istanbul	0.4	0.29	0.29	0.27	0.27
Tivat	0.78	0.90	0.90	0.16	0.16
Podgorica	0.73	0.90	0.90	0.23	0.24

Let us assume that upper boundary for the  $p_{sf}$  is 0.5. Routes with the value greater than 0.5 will be operated by small aircraft, otherwise - by medium size aircraft. The outputs from this stage are two subsets of routes: the first subset presents routes covered by small aircraft and the second one presents routes covered by medium size aircraft. Destinations from Belgrade to Vienna, Prague, Skopje, Sarajevo, Tivat and Podgorica, together with Thessalonica and Ljubljana are covered by small aircraft, while routes to Brussels, Copenhagen, Athens, Rome, Frankfurt, Düsseldorf, Berlin, Zurich, Istanbul, Milan, Munich, Stuttgart (from fuzzy logic system), Paris, Amsterdam, Stockholm, Gothenburg, London, Moscow and Monastir (known) are operated by medium size aircraft.

Relative errors (Table 1) are acceptable for all destinations, except Prague and Athens. This exception can be explained by the fact that there have been no flights between Belgrade and Prague in recent years, so use of a small aircraft is expected on newly opened routes.

In order to determine the required number of small and medium aircraft, it is necessary to determine flight frequencies (weekly) and define a timetable (departure times) for the assumed route network. The earlier research indicates a close link between flight frequency and aircraft size, [11], [9], [8]. An airline should make decisions related to flight frequencies and aircraft size for the observed route, while estimated traffic for known demand on some route depends on market conditions (competition, passenger profile, distance, airports, etc.). The estimated demand, previously determined aircraft size (small or medium aircraft) and existing frequencies (partially) will be considered for flight frequency determination due to the fact that a new airline is entering the established market. Some assumptions are introduced: minimal weekly frequency is 2, while maximal frequency is 28. Maximal frequency limit is introduced because of the fact that the airline is not large, so higher frequency would not be reasonable in the observed competitive market.

Forecasted total passenger flows from Belgrade Airport to the selected countries are obtained by multiple linear regressions, while flows by airports are results of historical data, market conditions and expert opinion [6]. Average weekly number of passengers and adopted frequencies are given in Table 2.

According to [1] recommended passenger load factor of 75% is acceptable for an airline. Therefore, minimal and maximal frequencies for 75% load factor are calculated as the average value of minimal values for 2012 and 2015, and maximal frequencies are calculated as the average value of maximal values for 2012 and 2015. The adopted value of frequency for the selected route (Table 2) in most cases is the maximal value if it is an even number (for routes to Brussels, Copenhagen, Paris, Rome, Milan, Munich, Stuttgart, Berlin, Ljubljana, Sarajevo, Istanbul, Tivat and Podgorica) or the first smaller if it is an odd number (Vienna, Amsterdam, Frankfurt, Düsseldorf, Stockholm, London, Prague, Moscow, Zurich and Monastir).

Route to Gothenburg has the adopted frequency equal to 2, because this value is set as a minimal weekly value. There are some exceptions in the case of route from Belgrade to Thessalonica and Skopje. For these routes, the minimal value of frequency will

be adopted, due to the fact that Athens and Thessalonica could be considered as one, Greek, market, while the air market of FRY Macedonia (Skopje) has good connections to Serbia by road transport.

**Table 2. Weekly frequencies on route network**

City	Weekly passenger demand		Adopted frequency
	2012	2015	
Vienna	940	1208	28
Brussels	147	189	2
Copenhagen	267	343	4
Paris	1469	1887	22
Athens	846	1087	12
Thessalonica	470	604	6
Amsterdam	360	462	4
Rome	646	830	10
Milan	129	166	2
Munich	417	536	6
Frankfurt	1143	1469	16
Stuttgart	245	315	4
Düsseldorf	998	1282	14
Berlin	817	1049	12
Stockholm	206	265	2
Gothenburg	69	88	2
London	1293	1661	18
Prague	176	226	4
Ljubljana	382	491	12
Skopje	1028	1321	16
Moscow	1557	2001	22
Zurich	1360	1747	20
Sarajevo	588	755	18
Monastir	214	275	2
Istanbul	661	849	10
Tivat	727	934	22
Podgorica	516	662	16

### 3. FLEET SIZING MODEL

The fleet sizing model refers to a minimal number of aircraft which an airline needs to operate a planned flight schedule. The number of small and

medium aircraft is determined separately, using simultaneous and sequential heuristic approach. The simultaneous heuristic algorithm consists of the following 5 steps:

*Step 1:* Make a list of all flights planned for one week, sorted according to the departure time and day in the week (start with the flight with the earliest departure time in the first day in the week, and finish with the last flight in last day in the week).

*Step 2:* Assign the first flight to the aircraft 1.

*Step 3:* Consider the next flight from the list. Assign it to some of the already introduced aircraft if time (departure time is after the arrival time of the previous flight) and space (departure airport is actually the arrival airport of the previous flight) constraints are satisfied. Otherwise, introduce a new aircraft.

*Step 4:* If the flight can be assign to more than one aircraft, choose the aircraft which is available in the earliest time. If there is more than one aircraft with the same time when they are available, choose arbitrarily between one of them.

*Step 5:* If there are no unassigned flights on the list, end the algorithm. Minimal number of aircraft is the number of introduced aircraft. Otherwise, go to the Step 3.

The second approach is the sequential heuristic procedure which consists of the following 4 steps:

*Step 1:* Make a list of all flights planned for one week, sorted according to the departure time and day in the week (start with the flight with the earliest departure time in the first day in week, and finish with the last flight in the last day in the week).

*Step 2:* Assign the first flight to the aircraft 1. Then go through the list assigning to this aircraft the next flight which has the earliest possible departure time, until the end of the list, considering time and space constraints, and the fact that departure airport in the first day must be the same as the arrival airport in the last day in the week.

*Step 3:* Take the first flight from the list which is not assigned to any aircraft and introduce a new aircraft repeating the procedure from the Step 2.

*Step 4:* If there are no unassigned flights on the list, end the algorithm. Minimal number of aircraft is the number of introduced aircraft. Otherwise, go to Step 3.

The algorithm is applied day by day considering space constraints (aircraft must start new flight from the airport where it is finished previous flight) and aircraft balance (it is necessary that required number of aircraft is available at each airport).

The planned flight schedule of the incumbent airline is the existing one (existing airline's), extended to some new routes and frequencies. It

consists of 304 flights in total, 184 operated by medium aircraft, and 122 operated by small aircraft. Algorithms are applied day by day, separately for small and medium aircraft. Both give the same solutions – the same number of aircraft by day. Difference between solutions obtained by these two algorithms represents the balanced flight hours in the solution obtained by the simultaneous approach compared to the sequential approach, where the firstly introduced aircraft operate much more flights than the lastly introduced aircraft. Minimal daily required number of small is equal to 3 during the whole week, except for Sunday, when it is equal to 4. The airline needs 9 aircraft three days per week (Tuesday, Wednesday, and Thursday), and 8 medium size aircraft four days per week.

Now, the question is how many aircraft the airline should order? Is the answer 4 small and 9 medium aircraft, or 3 small and 9 medium aircraft, or 3 small and 8 medium, or something else? These are some of the possibilities that may be adopted by the airline. The decision depends on the planned flight schedule and demand. Schedule could be designed in such a way so that some small aircraft could operate flights to which medium aircraft is assigned, and vice versa, and demand could also allow this change in aircraft size. In the case of the incumbent airline presented, the minimal required number of small aircraft is 3, because flight schedule allows one of the medium size aircraft to operate flights assigned to the fourth small aircraft.

Moreover, an airline could try to adjust its flight schedule, by changing departure time of some of the flights, day of operation or reducing the frequency so as to enable reduction of the minimal number of aircraft.

Another solution is to find an appropriate proportion of acquired to leased aircraft. According to [7] an optimal share of leased aircraft within the total fleet is 40%. Their conclusion is based on the data of 23 leading airlines. As the airline described in this paper is not a leading one, additional research is required to determine this share.

#### 4. CONCLUSION

This paper presents the two-stage fleet planning model consisting of fleet mix and fleet sizing models. Fuzzy logic approach in determination of approximate fleet mix within the fleet planning process is introduced and it presents the main contribution to the literature. The input data in this stage are based on passenger demand on route and route distance. The outputs from this stage are a set of routes operated by small aircraft and a set of

routes operated by medium size aircraft. At the same time, the abovementioned outputs are input for the second stage. The heuristic algorithm with two approaches is developed to determine a minimal number of aircraft which an airline needs to implement a planned flight schedule.

Fleet planning is a process of strategic importance for an airline that has a tendency to match their capacities and passenger demand for corresponding market conditions. Good fleet plan has a direct impact on airline profitability and costs. Thus, when choosing aircraft for fleet, both the interests of the airline and passengers must be taken into consideration. The airline is interested in carrying out the planned traffic with the least possible number of aircraft, the lowest possible operating costs and the highest aircraft block time and passengers load factor. Passengers are interested in high flight frequencies, large number of non-stop flights, small connecting time, etc. These conflicting interests need to be harmonized. Airline planners in charge of strategic planning very often have to make certain decisions dealing with uncertain and approximate values of input parameters. Huge experience of airline planners is incorporated in fuzzy logic system presented in this paper in order to make easier decision making related to approximate fleet mix.

The advantage of the model is that it could be applied in the case of cargo airlines with minor adjustment related to specific characteristics of air cargo transport. Depending on freight demand and distance airline will choose medium or large aircraft in the approximate fleet mix model, while fleet sizing model could be applied without changes.

Further research can focus on improving the solution in fleet sizing model in terms of a more balanced number of flight hours by aircraft. Another possibility to extend this research is to make additional analysis in order to consider leasing/buying share of aircraft in a fleet. Finally, with regard to decision making related to aircraft acquisition (aircraft types), this research could go further with deeper analysis of aircraft types, aircraft prices, fleet commonality and other factors that may influence aircraft selection.

## ACKNOWLEDGMENT

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**Part II**

**INFORMATION  
TECHNOLOGIES IN LOGISTICS**

# ARCHITECTURE OF INTEGRATED GIS AND GPS FOR VEHICLE MONITORING

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**Abstract:** In this paper, system architecture for vehicle monitoring will be presented. The architecture consists of GPS part for collecting information of vehicle position at the moment of observation, spatial database part for storing this information after refining, and in the end, Geographic Information System (GIS) subsystem. Having used GIS, it is possible to display information on a digital map. The methods of GPS collecting and preparing information will be described in details, especially the method used within a moving object. The spatial database stores information about location (latitude, longitude and elevation) at the time of observation, and some additional desired attributes. GIS provide information to a user by queering and calculating distances to some point and other function.

**Keywords:** Web GIS, GPS, Vehicle Monitoring, GIS-GPS System Architecture.

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## 1. INTRODUCTION

With the rapid development of economy, there are new requirements for tracking and monitoring of moving objects in real time. Industrial development increases the need for transportation and operational management. Logistics management transporting systems become very important in monitoring vehicles during transport. The development of global positioning technology has made possible positioning of a moving vehicle.

As a wireless communication technology also achieved great progress, it provides a method for remote monitoring and control of a moving object. Many logistics companies, as well as civilian vehicles, are beginning to apply GPS technology to accomplish functions such as positioning, navigation and surveillance.

GPS vehicle tracking system plays a very important role in achieving these goals. It integrates global system for mobile communications (GSM), Global Positioning System (GPS) and geographic information system (GIS) in one system. Such compositions technology allows upgrading system for vehicle monitoring. [1]

The rest of the paper is organized as follows. System architecture and every module are presented in second chapter. Third chapter describe the system

component and technologies. In fourth chapter, functioning of the system will be discussed. In the fifth chapter, conclusion with some future research will be given.

## 2. SYSTEM ARCHITECTURE

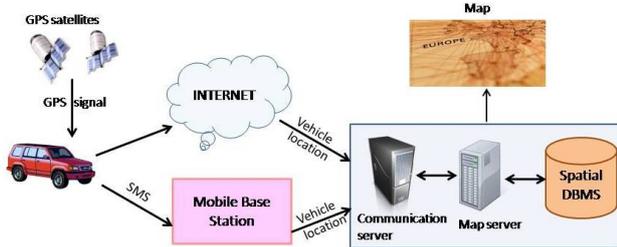
In order to present system architecture, some basic functions of software application discussed in this paper need to be presented. This vehicle monitoring system platform is based on GIS and GPS technologies using GSM network and Internet.

This application is applicable to operation of the logistic industry such as vehicle tracking, vehicle management and vehicle dispatch. System network is depicted on Fig. 1. In order to provide vehicle monitoring and management, system is capable to satisfy following functions:

- Display of interactive electronic map. It is possible to pan, zoom, view tips about feature, edit feature, and control multiple layers.
- Vehicle real-time monitoring part (Communication server) receives short messages or message sent via Internet, which consists of vehicle geographic position and working state. This message is then translated into suitable format, and

vehicle information displayed in the electronic map and data in the data grid.

- Query implements query of general information about a vehicle and query of history records satisfying certain conditions.
- Task allocation sends task schedule orders to the specified vehicles, receives response information from vehicles and processes alarm info automatically if an accident happens.
- For history positions of vehicle, selected records from history database meeting specified conditions can appear on map.



**Figure 1. System network for vehicle monitoring**

Every vehicle has a part which is installed on the terminal vehicle and which is responsible for receiving GPS satellite positioning signal. This signal contains position which is extracted and then sent to the monitoring center. The monitoring center can receive position information distributed by the vehicles. The monitoring center can control the terminal vehicles. Display, query and control of this information are realized through the monitoring center software.

### 3. SYSTEM COMPONENTS AND TECHNOLOGIES

System architecture, provided in previous chapter, is made of vehicle terminal, server for GIS map, communication server and also uses Internet and GSM mobile network for exchanging information between vehicle terminal and monitor center.

The earliest interest in geographic information system dates back to 1960. year. GIS technology integrates basic operations with the database, such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by map. [2] Among other things, GIS facilitates the modeling of spatial network (road network), offering algorithms for querying and analysis.

Spatial networks are modeled graphs. In the case of transport networks, arcs correspond to street

segments as nodes correspond to the corners. Each arc has a weight, which is the impedance (price) passing that part time (segment). In most cases, the arc impedance is a function of appropriate length of street segments and traffic density.[3]

In this study, for the development of systems for tracking and monitoring of vehicles in real time, and integrating four different high technology: GPS, GIS, GSM and SMS. The most used technologies are described in the following part.

#### 3.1 GIS – QGIS

In this paper, for GIS function implementation, QuantumGIS [4] has been used. QuantumGIS (QGIS) is a powerful and user friendly open Source Geographic Information System that runs on Linux, UNIX, Mac OSX, Windows and Android. QGIS supports vector, raster, and database formats. QGIS is licensed under the GNU Public License.

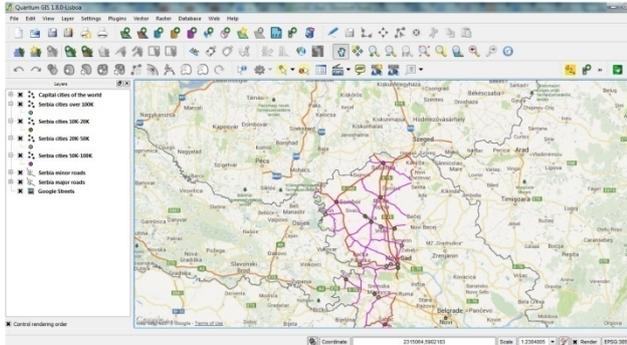
The QGIS project offers different applications for different use cases. QGIS Desktop (the classic QGIS desktop application offers many GIS functions for data viewing, editing, and analysis). QGIS Browser (a fast and easy data viewer for your local, network and online (WMS) data). QGIS Server (a standard-compliant WMS 1.3 server that can be easily configured using QGIS Desktop project files). At the end, QGIS also has its own Client (web front-end for your web mapping needs based on OpenLayers and GeoExt).

GIS software of the system is developed based on Quantum GIS desktop tool for creating maps and Geoserver, which is a mapping control that has easy and powerful mapping capabilities for applications. With maps, information can be displayed in a format that's easy for everyone to understand.

Maps are more informative than simple charts and graphs, and can be interpreted more quickly and easily than spreadsheets. Fig. 2 shows the main user interface of the Quantum GIS software, which displays the vehicle information in map format. OpenLayer plug-in for Google Street is on the bottom of the layers, followed with the cities represented with points and roads represented with lines, in the north Serbia. These features are necessary for building this vehicle tracking and monitoring and this map will be filled with more data in the future.

GeoServer [5] is an open source server software written in the Java programming language that allows users to share and edit spatial data. Designed for interoperability, publishes data from any major spatial data source using open standards. Since the project is an open community of people, GeoServer is developed, tested and supported by different

groups of individuals and organizations from around the world. It is fully compliant with the OpenGIS Consortium's web services specification; Web Map Server (WMS) and Web Feature Server (WFS). GeoServer is available under the GPL 2.0 license.



**Figure 2. Vehicle road distribution in QGIS map with OpenLayer support**

### 3.2 GIS – Geoserver

GeoServer allows the display of spatial information in the world. The implementation of standard web map services (WMS), GeoServer can generate maps in a variety of output formats.

GeoServer also supports Open Layers for making map generation quick and easy. Spatial queries in GeoServer are possible with the combination of PostgreSQL/PostGIS DBMS. There is a performance comparison between GeoServer and MapServer, another famous open source IMS.[6] OpenLayers is a free library for mapping, which is integrated into GeoServer, to quickly and easily generate a map. GeoServer is built on Geotools-in, open source Java GIS tool.

It is much more than the map generator. GeoServer also supports Web Feature Service (WFS) standard, which allows sharing and editing the data used to generate the map. Others may turn their data into their websites and applications, freeing up your data and allows greater transparency.

### 3.3 GIS – OpenLayer

OpenLayers [7] technology is also used in this application. It is a JavaScript library for displaying dynamic map data in any web page without server side dependencies. This web page views the mapping services published by Geoserver using the OpenLayers web mapping library. The OpenLayer is open source, making it flexible and capable across standards as well as proprietary application programming interfaces (APIs). It allows to use any of the tile sets provided by Google, OpenStreet Map, Microsoft and Yahoo, all within the same programming API.

### 3.4 GPS

Global Positioning System (GPS) is a space global navigation satellite system. In this paper, information that GPS offer are crucial. It provides reliable positioning, navigation and time services on a continuous basis in all weather, day and night, anywhere on or near the Earth. GPS consists of three parts: between 24 and 32 satellites that orbit the Earth, the four cells for the control and monitoring of the Earth, and the GPS receivers owned by users. GPS satellites broadcast signals from space that are used by the GPS receiver and a three-dimensional position (latitude, longitude, and altitude) plus the time. In this study, for the development of systems for tracking and monitoring of vehicles in real time, and integrating four different high technology: GPS, GIS, GSM and SMS.

Global Positioning System (GPS) technology has created a revolution in surveying and mapping around the world. It is a technology that offers great potential to GIS, where data collection has proven to be the most limiting factor to successful implementation and use. GPS was established by the U.S. Defense Department to transmit signals that can be used to generate highly precise location data. Use of the technology requires operation of specially developed GPS receivers and accompanying software. The receivers capture the signals transmitted by the satellites to calculate and record the data digitally. Specially designed software is then employed to calculate position data from the signals.

Numerous types of receivers are now available in the marketplace making use of multiple approaches to the signal capture and generation of position data. The individual approaches provide various levels of accuracy under differing conditions and at differing costs. In general, with each approach, the receiver locates and “locks onto” multiple (generally 4 to 6 or more) satellites and records the signal from each of the satellites digitally.[8]

The satellites transmit multiple coded signals that are interpreted in various ways among the approaches. The data thus recorded are analyzed by software that compares the various satellite signals and pre-recorded control parameter data to generate latitude, longitude, and elevation data.

The GPS consists of a specially designed receiver, an antenna, a data recording or logging device, and possibly other devices for recording additional data observed at the location. Operation also requires a computer for processing the data. Interface devices are necessary to upload data to a PC or other processor. Since the system is ultimately

operated by the military and can potentially be used by an enemy, security is a key consideration. The signals are continuously modified and can be encrypted to provide security in times of threat. The reality of that risk is probably quite minimal in today's international environment. The growth of a very large industry around the technology further ensures its continued availability.

There are other satellite navigation systems: Galileo is a European Union Global Positioning System, Glonass is a Russian and BeiDou (or COMPASS) is the Chinese system.

### 3.5 GSM and SMS

SMS (Short Message Services) is an important technology that has made a serious impact on our everyday life. It enabled ubiquitous communication channel to be extended for feature rich value added services. SMS technology has helped tracking vehicles, criminals and also has the potential to become a channel for launching cyber attack. It has the potential to be a channel for launching DoS attack and triggering malware. It has also helped law enforcement agencies to track adversaries.

### 3.6 Spatial database - PostGIS

In early GIS implementations, spatial data and related attribute information were stored separately. The attribute information was in a database (or flat file), while the spatial information was in a separate, proprietary, GIS file structure. For example, municipalities often would store property line information in a GIS file and ownership information in a database. Spatial databases were born when people started to treat spatial information as first class database objects.[9]

Spatial database stores spatial object and manipulate that spatial object just like other objects in database. Spatial data describes either location or shape (house, river, parks, lakes), and in abstract view, these entities are represented as points, lines and polygons.

Many DBMS offer spatial functionalities, some are: ESRI ArcSDE, Oracle Spatial, IBM DB2 Spatial Extender Informix Spatial DataBlade, MS SQL Server (with ESRI SDE), Geomedia on MS Access, PostGIS / PostgreSQL. In this paper, PostGIS[10] for PostgreSQL has been used. PostGIS is a spatial extension for PostgreSQL DBMS and aims to be an "OpenGIS Simple Features for SQL" compliant spatial database. PostGIS spatially enables PostgreSQL by adding spatial objects, functions, and indexing. It is free software and an important component in open and free GIS and important

building block for all future open source spatial projects.

Generally, spatial databases are able to treat spatial data like anything else in database (transactions, backups, integrity checks, less data redundancy, fundamental organization and operations handled by the DB, multi-user support, security/access control, locking).

Using SQL expressions, spatial querying is able to determine spatial relationship (distance, adjacency, containment) and also to perform spatial operations (area, length, intersection, union, buffer).

## 4. FUNCTIONING OF THE SYSTEM

GIS has been increasingly used to support AVL (Automatic vehicle location) and IVHS (Intelligent Vehicle Highway System) applications.[11] In this case, the GIS maintains a base map of the street system and necessary reference features on which the vehicle location is displayed or along which routing or other spatial analysis functions are performed.

The GPS is used to provide the real-time location of the vehicle to be displayed or routed with this base. In this use, the vehicle to be located has a GPS receiver mounted and continuously operating. This is a real-time data collection and management effort requiring very sophisticated system. Also, GPS is also used to create the base file of the street network to be used in this application.

The design and implementation of the prototype show that it is feasible to develop a system such as the one described in this paper using open source GIS software. However, the problem of join descriptive data using a CSV file with a geographic data in QGIS was discovered. Excel encodes this CSV file using ANSI (American National Standard Institute) character set.

In QGIS, text features from outside QGIS cannot be pasted to a layer within QGIS. As a result, there is a language error for the join descriptive data. We suggest one of the solutions for this problem by using PostgreSQL/PostGIS capabilities. First, it is necessary to convert an ANSI CSV file to a UTF-8 CSV file by using Notepad or EditPlus. UTF-8 is appropriate for writing code for cross-platform software. Second, an Unicode CSV file is imported into PostgreSQL/PostGIS. Then, descriptive data in the CSV file can be joined with a geographic data by using the joins tab in PostgreSQL/PostGIS.

Technically, this vehicle monitoring system comprises two virtually connected parts: vehicle-mounted subsystem (GPS), monitoring and

communication subsystem. Functioning of each is described in following parts.

#### 4.1 Vehicle GPS terminal subsystem

Vehicle GPS subsystem functions are to communicate with the monitoring centre by sending information such as vehicle position and vehicle status. Main functions of the vehicle GPS subsystem are:

Sending positioning information: GPS receiver will do positioning in real-time and send the positioning information, using SMS, to the monitoring center.

Data display: display real-time position of the vehicle, such as the longitude, latitude, speed and heading direction.

Receiving dispatch instructions: receive dispatch instructions sent from the monitoring center, and display or give out voice on the display element.

Alarm: in case of emergencies, the driver will initiate the alarm device, and the monitoring center will display information about the vehicle conditions, position of accident and the vehicle and personnel.

#### 4.2 Monitoring center subsystem

The main functions of monitoring center subsystem are about processing, displaying and managing the vehicle position and alarm information received. According to these functions, it mainly consists of GPS and alarm information receiving subsystem, GIS subsystem, information management subsystem and data maintenance subsystem.

According to this multiple subsystems, monitoring center provide all information about moving vehicle. All these information are available in spatial database.

### 5. CONCLUSION

Solution presented in this paper is simple and have low implementation cost. Systems that connects GPS and GIS technologies for vehicle monitoring system has a great future in the transportation

industry. Using open source GIS; Quantum GIS, PostgreSQL/PostGIS and GeoServer are feasible to develop an application of GIS. Further research will be focused on spatial database optimization for better querying spatial object and features.

### ACKNOWLEDGMENT

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## BI APPLICATIONS IN LOGISTICS

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***Abstract:** Contemporary business conditions in the global market require a fast and efficient decision-making. The basis for quality decision-making are the right information at the right time and the right place. The development of information and communication technology – ICT has led to the generation and collection of large amounts of data on business resources, processes, markets and customers. The key to a successful business becomes the possession of quality information and decision making based on the current state of the business system and market demands. Business Intelligence – BI is a set of methodologies, processes, architectures, and technologies that enable the processing of large amounts of data and their transformation into a high-quality and useful information and knowledge. This paper will describe the BI technology and the possibilities of its applicability. In particular, it will show the effects of BI in the field of logistics.*

***Keywords:** logistics, business intelligence, data warehouse, decision making, reporting.*

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### 1. INTRODUCTION

In contemporary market conditions, information and knowledge are the key elements for effective decision making. Business systems monitor their performance, results and performance indicators and according to market demands and competition's behavior, make decisions about their plans, market expansion, operation and future development. Modern information systems - IS enable the support of business processes, collection and processing of business data and obtaining reports on work concerning the activities, processes, or the entire system. Global market and fierce competition have imposed new demands on business systems: the speed of reaction and decision-making based on large amounts of data on previous and current operations. This has led to the need for the right information at the right time that will enable the creation of new business value.

Business Intelligence – BI is a modern approach to processing large amounts of data, their transformation into high-quality information and presentation possibilities in a form that corresponds to the users. Historically, BI is continued development of the IS that give support to decision making in a business system. A necessary condition for the development of BI systems is the existence of

a modern technology of data storage. Traditional database systems are oriented towards the storage and processing of individual transactions and do not provide access to information and an integrated view of the business system. DWH (Data Warehouse) is a database technology that provides access to business information with high performance and safety.

This paper will describe the BI technology, possibilities and examples of its application in the field of logistics. The paper consists of four parts. The first part describes the DWH technology. The second part includes a description and advantages of the BI technology. The third part shows the possibilities and examples of application of BI in the field of logistics. Concluding remarks are in the fourth part.

### 2. DATA WAREHOUSE

Data Warehouse – DWH is a modern database technology that provides input, storage and processing of heterogeneous data from different sources in order to provide a solid basis for the analysis and reporting to end-users. From the system point of view, DWH corresponds to the organizational scheme of the business system, from the level of the data source to the decision-making level. From the technological point of view, DWH is a set of layers that provide reception, transformation,

processing and online analytical data processing. DWH system facilitates the storage and processing of large amounts of data from integrated heterogeneous sources in optimized multidimensional data patterns.

Some of the reasons for designing the DWH system are [7]: Integration of data with business functions and processes in order to obtain a complete picture of the individual parts or the entire business system; The possibility of simultaneous execution of large queries and reports, and routine operation of business users with other features of the system; Reorganization of data in order to perform reports and queries more quickly; and Ensuring quality through a strict check of data entry – the consistency and integrity of data.

The development of the DWH system is very complex and requires ad-hoc methodologies and the appropriate life cycle. In literature there are three approaches to the development and maintenance of the DWH system: system pattern evolution, the development of different versions of the pattern and system maintenance [3]. Changes in the DWH system are inevitable in practice because it needs to correspond to the real business system and its requirements. Today there are developed quality software tools that enable maintenance of the DWH system and a consistent implementation of changes in all layers. An example of the DWH architecture is shown in Figure 1.

Data is collected from various internal and external sources: different transactional database off line import of data from files, manual entry of data from documents, import of data from ERP (Enterprise Resource Planning) and CRM (Customer Relationship Management) systems, and import of data from external systems (suppliers, Point of Sale – POS, banks, etc.). ODS (Operational Data Storage) layer receives and stores all data from internal and external sources. ETL (Extraction, Transformation and Loading) layer checks the consistency of data in accordance with the defined rules, establishing relations of data integrity and charges the data patterns in the DWH. In the summary layer the aggregation of data is done at different levels of detail according to the needs of analytical data processing. The analytical layer includes a set of data models, which are the basis for the generation of different reports, as defined in the business system. The OLAP cube are data models designed to meet the needs of OnLine Analytical Processing data. Data mart is a logical subset of the DWH defined according to the specific needs of the business process or user groups, in order to obtain

various business reports that support the making of actual decisions.

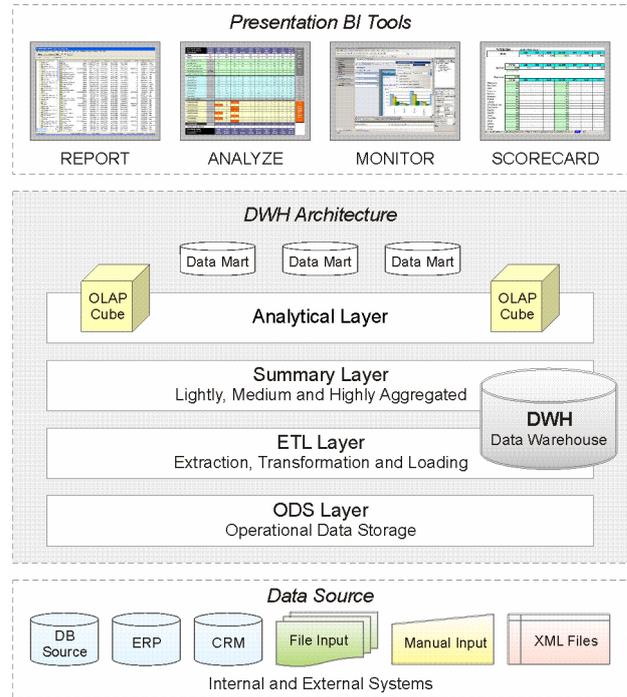


Figure 1. DWH architecture

### 3. BUSINESS INTELLIGENCE

Business Intelligence – BI is a set of methodologies, processes, architectures, and technologies that transform raw data into meaningful and useful information and knowledge. BI provides business information and the analysis of key business processes, quality decision-making at different management levels and improvement of the performance in the business system. The role of BI in the process of decision making is shown in Figure 2.

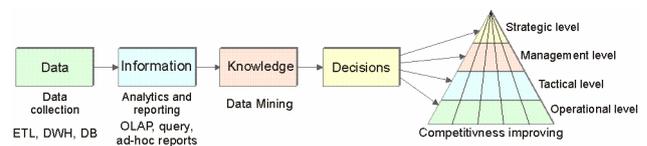


Figure 2. The role of BI in the decision-making

The development of information technology – IT has enabled the development of modern platforms to help work with large amounts of data. On one hand, the volume of data being generated and stored in business systems is constantly growing, and on the other hand, there is an increasing number of users and their needs for high-quality information and new knowledge. BI meets the requirements of business systems because it can get information quickly, reliably and in an appropriate form.

The BI system can be observed from different angles. The BI system allows the transformation of data into information and knowledge, thus creating new conditions for decision-making in the business system. Decision-makers in a business system use the BI analytics to support adoption of quality and timely decisions at all management levels. The real value of the BI system is reflected in the added value that is generated: better understanding of one's own resources, the implementation of changes in the business system, opening of new markets, acquiring new users, etc.

In almost all business systems there are developed reporting systems that are based on traditional approaches and are a standard part of the IS and ERP systems. These reports are usually standard, historical and static. Classic reports do not have the ability to analyze data on a variety of business processes, monitor business performance in real time, link data from various organizational levels and perform planning that aligns business strategy and financial objectives.

BI enables overcoming of these problems and provides new opportunities to business systems in the context of fast market changes. BI refers to all business processes and activities, includes all data and transform them into reliable and quality information providing timely response to business issues. The right information at the right time and the right place is a prerequisite for making decisions at the operational, tactical and strategic level, and quality decision-making leads to the creation of additional value in the business system.

BI is a modern and contemporary approach to the monitoring of the business system, which requires specific hardware and software infrastructure and the DWH system. The central part of BI technologies are analytics and reporting, which, on the modern IT platform, got new possibilities in terms of application of analytical and statistical models, BI application integration with other business systems and the possibility of different forms of presentation. Forrester's research shows that the BI technology is evolving and that companies, based on new trends, can gain a competitive advantage in their fields [1].

The BI system consists of a number of applications that are designed for analytics and reporting on certain processes, performances, causal relationships that exist between different parts of the system or are created according to specific customer requirements. The use of these applications can indicate the performance of the process and of the entire system, the analysis of deviations and proposal of measures that lead to improving

productivity. Standard reporting systems provide quantitative characteristics in form of tables, which makes it difficult to realize the causes of deviations from planned values. BI uses data at different levels of aggregation, has the ability to connect with analytical models and a good visualization of the output, which makes information easier, faster and simpler for use and decision-making.

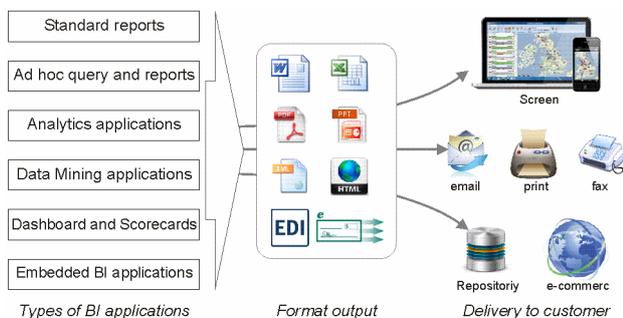
BI platform enables the development of different types of applications depending on the method of data processing, complexity, user interaction and form of presentation of information. The main types of BI applications are [2]:

- **Standard Reports** are predefined reports that use data from the DWH system through developed data models. They enable a smaller amount of interaction with the user through the input of certain parameters that define the extent of reporting. This type of application is commonly used for reporting systems that are essential in the daily operations of the user.
- **Ad-hoc queries and reports** allow users to search data through multidimensional data models (the OLAP cube). Simple Ad hoc tools provide results in the form of tables, while advanced tools provide forming of complex reports. Ad hoc reports are made when needed and are a response to the current customer requirements.
- **Analytical applications** are complex reports that combine different sets of business information sorted according to certain characteristics, with one or more approaches for information analysis. These applications are related to the analysis of specific business processes and activities.
- **Data mining applications** are developed in more advanced BI systems where there are already other types of applications in use. They are associated with the transaction systems and / or other business applications. Typical examples are applications for the prevention of fraud with credit cards and e-business applications. Both examples are based on an analysis of historical transactions to identify patterns of behavior and in real time prevent the abuse of credit cards, that is, propose purchase of additional products based on previous purchases.
- **Dashboards and Scorecards** are the most advanced version of BI applications because they include a large collection of data relating to different business processes and

the visualization of results in a way that is fastest to present new information and knowledge to the user. Dashboards are most commonly used to monitor and manage processes and activities, ensuring monitoring changes in real time. Balanced Scorecards is an approach of monitoring business performances from different aspects, which enables users to monitor the current situation and provides the possibility to warn of future changes.

- **Embedded BI applications** are much more sophisticated than the standard operational reports. These applications handle historical data from the DWH on a variety of business processes in order to provide support for making operational decisions. Embedded BI applications are associated with other business applications to which they forward the results of processing. They are often associated with DM techniques to help identify patterns at the operational level.

BI applications can have different output data formats (interactive, HTML, PDF, RTF, Excel, PowerPoint), which can be displayed on screen, printed, e-mailed or faxed to customers or stored in a repository or used as documents in the e-trade (Figure 3).

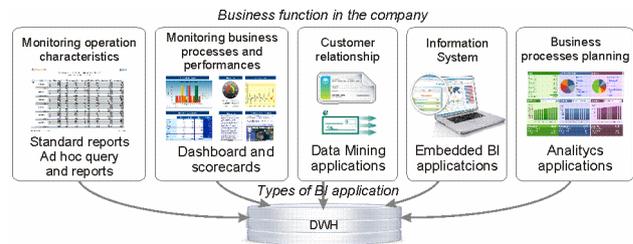


**Figure 3. Various formats of BI applications output results**

BI applications can be run on demand, automatically at specified time periods, or after certain events in the business system. For example, reporting applications that run on a daily basis for managing customers, accounts and invoices for payment delivered at the beginning of the month to customers via e-mail, analytic applications that are executed when the value of sales falls below the defined level.

The main issues raised by the improvement of operations and improvement of business performance are *how is it done now* and *why*, and *how it should be done*. The answers to these questions have a direct impact on the future way of

doing business. BI allows monitoring and management of the business system through different types of applications that provide an immediate response to the user on the state of business processes and activities. Figure 4 shows an example of business functions in a company and different types of BI applications that support them.



**Figure 4. Business functions and BI applications**

The application of BI in the business system can provide: improvement of the operational functioning of business processes, and improving the business system management process [8].

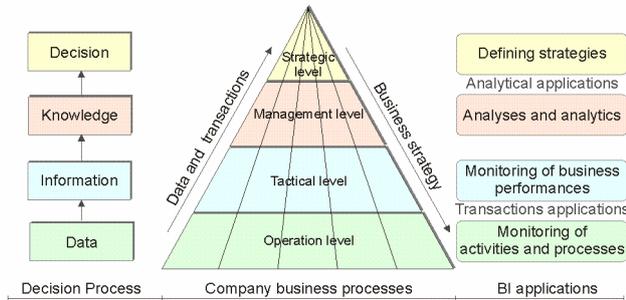
#### 4. BI IN LOGISTICS

Business organization and decision-making system in a company can be schematically represented in the form of a pyramid. In accordance with the hierarchy, business processes and organization of work, there are four organizational levels in a company: operational, tactical, managerial and strategic [5]. Horizontal and vertical integration include information flows that are exchanged at the same level or between different organizational levels. The existence of high-quality and reliable information is the basis for effective decision making at all levels in a company.

The application of BI in a company can be realized at all levels of organization so that the BI applications support business processes and the decision-making system. Various types of applications are used to support the operational tactical, managerial and strategic management (figure 5):

- At the operational level it is necessary to monitor the operation of the activities and processes in real time - standard reports;
- At the tactical level the values of business performances and key performance indicators are monitored (Key Performance Indicators – KPI) – dashboards and Scorecards;
- At the management level the analysis and the analytical data research are done, after being obtained from the lower system levels – analytic applications; and

- At the strategic level, planning and forecasts are done, and based on that, in accordance with the financial resources, business strategies are defined.



**Figure 5. The application of BI applications at different levels decision-making**

The hierarchical structure of the decision-making process, from the data to decision making, corresponds to levels of decision making in the business system, and BI applications are the support to business functions at different levels.

In the field of logistics BI systems can be applied in all companies that manufacture the products and/or provide services – production systems, logistics and distribution centers, goods terminals, storage systems, fleet management, retail, etc. The application of ICT in logistics has enabled automatic generating and storing of large amounts of data related to the processes and activities in a company, customers, business partners, participants in the supply chain, market conditions, etc. In a large number of companies the data is not analyzed sufficiently in order to take full advantage of the information and acquire new knowledge. The BI technology allows the processing, analysis, and data analytics, in order for companies to improve their performance and achieve competitive advantage.

The applications of BI in logistics can be divided into the following groups:

- KPI – BI applications enable monitoring of key performance indicators of all the activities and processes in near real time. Contemporary models of reports provide quick and reliable information, rapid response in emergency situations, the automatic exchange of necessary information with other participants in the process, continuous monitoring of performance, etc.
- Warehouse Management – there are numerous examples of the use of BI applications in the analysis of inventory, survey and analysis of storage performance,

storage activities cost allocation, analysis of inflows and outflows from the warehouse, determining the allocation of goods and monitoring storage performance [6].

- Transport Management – BI applications can be designed for the analysis of transport costs, route planning and scheduling, performance analysis of drivers and vehicles, the analysis of delivery time cycles depending on various factors, capacity planning in line with expected demand trends, evaluation of the carrier that provides the service and analysis of the causes and consequences [6].
- Customer Relationship Management – The company exchanges information with its customers in the form of orders, invoices, reports on implemented services, payment reports, etc. The BI technology enables automation of all these activities by providing the users with the appropriate documents in defined time periods. On the other hand, analysis of the data collected on users gives the company new knowledge and makes it possible to create a custom offer for a particular user. In a similar way, BI applications can be used for managing relationships with business partners, customer analysis and resource planning.
- Management of services provided to users – BI applications enable better communication with users, management of elements of the service provided, analyzing of customer satisfaction, data analysis on user profitability, adapting to the needs and requirements of users etc.
- Supply chains – supply chains mostly use three types of BI applications: standard reports, dashboards and scorecards. Dashboards allow monitoring of realization of supply chains in near real time, and reporting of all links in the chain with necessary data. The main advantages of BI in supply chains are: following the realization and actual performance, increase of visibility, faster and more reliable exchange of information, improving the performance at the level of participants and at the level of chains, a better introduction to the events that generate additional costs, the ability to react quickly in case of delays, etc. [4].

In literature there are many examples of application of BI applications in logistics processes

and supply chains. Companies indicate a number of positive effects of application. Some of the examples are [8]:

- Western Digital, hard drive manufacturer with annual sales of more than \$ 3 billion, uses BI for better warehouse management, purchasing, product life cycle and CRM. BI has enabled the reduction of operating costs by 50%.
- CompUSA, selling computer equipment and software, use BI to analyze their sales trends. In the first phase of the BI system implementation they have earned more than \$ 6 million.
- TransCo is a large manufacturing company, with more than 4000 authorized dealers, over 2000 suppliers, hundreds of thousands of parts, and more than a million units in stock in its distribution centers in North America. TransCo use BI technology to track and analyze business performance in order to improve their services and reduce safety stock levels.
- Walmart has its promotion in the market tied to improving core business processes: planning, demand forecasting, sales, supply chain management and cost management. BI technology has been applied throughout the company, and many BI applications are used: to monitor their supply chains in real-time, to manage inventory and ordering, to process orders, and so on. Effects that are achieved go far beyond their competitors.

## 5. CONCLUSION

Today, the BI technology is applied in all areas, from the manufacturing and service systems, marketing, financial institutions to medicine, pharmaceuticals and sports. The BI can be applied wherever there is need to analyze large amounts of data in order to arrive at quality decisions, where sales and marketing are the basis of success, where it is necessary to decide fast based on current events, where a large number of transactions is monitored in order to reach conclusions, where there are a large number of products and clients.

The BI is applied in all logistic systems for monitoring performance, monitoring of business processes, receiving reports on systems operation and analysis of business indicators. The greatest advantages of the BI technology are: the possibility of an intuitive, clear and rapid reporting; shortening of time of submission of the report, possibility to submit the report in different formats and to different users, the possibility of integration of the BI applications with a variety of IS and ERP systems, development of the BI applications for various management levels of the business system etc.

## ACKNOWLEDGMENT

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## FROM TRADITIONAL ICT SOLUTIONS TOWARDS CLOUD COMPUTING IN LOGISTICS

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***Abstract:** During the last two decades Information and Communication Technologies (ICT) have strongly influenced organizational processes as well as logistics. Therefore, ICT provide many benefits in logistics sector, including time and cost reduction and improved efficiency and performance. However, new solutions and innovative ideas are constantly emerging which intrigues new possibilities for the reorganization of traditional logistics processes. The main idea of this paper is to provide comprehensive review and comparison of different ICT solutions and cloud computing (CC). Basic concept of CC, service models and opportunities of CC in logistics are particularly explained. As an emerging technology, CC is changing the form and function of information technology infrastructures making supply chain information collaboration easy and feasible. It can also be observed as an enabler of fully electronic logistics management systems. Adoption of CC concept involves strong hardware support, good Internet connectivity and implied reorganization of traditional business.*

**Keywords:** ICT, cloud computing, logistics.

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### 1. INTRODUCTION

Nowadays logistics involves a multitude of suppliers, manufacturers, carriers, logistics providers, and financial institutions that are essential to getting a product from origin and into customer's hands. Each of these partners owns a portion of the data that drives the logistics process, and each has a stake in the successful delivery of goods to the final location [1]. Global view, transparency of each phase during realization of logistics processes and comprehensive control over the crucial data are imposed as a priority in contemporary logistics. Therefore, Information and Communication Technologies (ICT) provide support for logistics processes and solve many logistics problems [2]. Constant progress of ICT field brings different solutions for dealing with arising problems in logistics and growing customer's demands. Cloud computing (CC) is among the most-discussed new technologies, and the current reality is that approximately 20% of discrete, process, retail, and wholesale manufacturers are using it [3]. In practice, CC enables that the data of each participants be uploaded, normalized and then embedded into the network where can be accessed if permitted.

Logistics resources and web services are two major aspects of cloud oriented logistics. Logistics resources have the characteristics of variability, geographical distribution, heterogeneity, morphological diversity and self-governing zone. Web services have the characteristics of distribution and heterogeneity in a cloud logistics platform [4]. Integrated into complexity of cloud network logistics resources present a platform for the virtualization of information and material flows. Therefore, reorganization of traditional logistics is imposed as a priority. CC allows scaling autonomous logistics applications flexibly based on the dynamically arising logistics demands [5]. The main goal is to facilitate smooth realization of individual and complex logistics services.

The traditional ICT approach provides solutions only for specific logistics jobs for which it is installed. In comparison with the CC approach the old way of doing business is costly, time-consuming and error-prone. Modern cloud-based logistics offers lower costs and collaboration in network where every new user that joins the network expands the list of potential partners in virtual supply chain making its connections and data available to all.

## 2. REVIEW OF ICT APPLICATIONS

Implementing different kind of ICT into logistics management can successfully improve and redesign logistics system, as whole, and also change customer's view on logistics [6]. ICT implementation and application requires great investment, thorough training sessions and constant learning [7]. There are various ICT solutions for different logistics segments on the market, and the most often used in logistics processes are: Advanced Planning and Scheduling (APS), Enterprises Resources Planning (ERP), Transportation Management System (TMS), Warehouse Management System (WMS), Radio Frequency Identification (RFID), Global System for Mobile communications (GSM), Global Positioning System (GPS), Geographic Information System (GIS), Wireless Fidelity (Wi-Fi), etc. Detailed explanation of mentioned technologies is beyond the scope of this paper.

Benefits of ICT applications in logistics are:

- EDI - reduce bureaucracy, streamlining and logistics costs;
- E-commerce - reduce prices, increase investments, facilitate marketing decisions, enable safety rules;
- APS - reduce costs, improve product margins, lower inventories and increase manufacturing throughput;
- ERP - improve productivity and transparency, integrate strategies and operations, reduce costs and risks, enable immediate access to enterprise information, improve financial management and corporate governance;
- TMS - facilitate tasks as transportation planning, performance measurement, control over vehicle loading and management of routes, distances and freight payments;
- WMS - manage and optimize operational and administrative activities along the warehousing process, which involves receiving, inspecting, labelling, storing, sorting, packing, loading, shipping, issuing documents and managing inventory;
- Barcode, RFID - support various logistics activities, such as picking, vehicle loading and unloading, order tracking and optimization of distribution routes;
- GSM - support maintenance of connections between subjects in logistics processes;
- GPS - support routing and tracking;

- GIS - enable visualization of key processes, high level of interoperability and data sharing, and provide comprehensive approach regarding logistics system as whole;
- Wi-Fi - offer possibility to exchange data wirelessly across logistics complex and establish high speed Internet, improve safety and security in logistics network, and propose unique standardization which facilitates outsourcing.

Disadvantages and challenges of ICT applications in logistics are [3]:

- ICT systems and business process incompatibility;
- Collaboration problems with partners, customers, and consumers;
- The high fixed cost of ICT;
- Limited resources available to solve problems
- Lack of data quality and consistency;
- Lack of access to systems and information;
- Lack of speed of implementation;
- Lack of transparency;
- Lack of a comprehensive view of the business;
- Inability to easily and quickly acquire new capabilities.

## 3. CONCEPT OF CLOUD COMPUTING

### 3.1 Basic Characteristics

CC shifts the frontier of ICT possibilities in modern business. Different complex software solutions and applications for business become available online and CC leads in that new trend. CC experts and administrators maintain, update and upgrade all the applications that each client requires. All the clients are simultaneously a part of a complex virtual network, which facilitate their business organization, because all the partners are interconnected constantly. Importantly, high quality of the data can be achieved, along with time savings and increased efficiency. By adopting cloud solutions an organization can focus on their core business, as cloud providers are obligatory to run ICT applications faster and more cost-efficiently.

Cloud computing characteristics are [8]:

- On-demand self-service;
- Broad network access;
- Resource pooling;
- Rapid elasticity;

- Measured Service.

Benefits of cloud computing adoption as new business concept are [9]:

- Cost containment;
- Innovation speed;
- Availability;
- Scalability;
- Efficiency;
- Elasticity.

### 3.2 Service models

Service models define what kind of services can be provided from the cloud. Depending on the chosen model, the provider offers and delivers different services. Three main service models are illustrated:

- 1) IaaS (Infrastructure as a Service),
- 2) PaaS (Platform as a Service), and
- 3) SaaS (Software as a Service) (Figure 1).

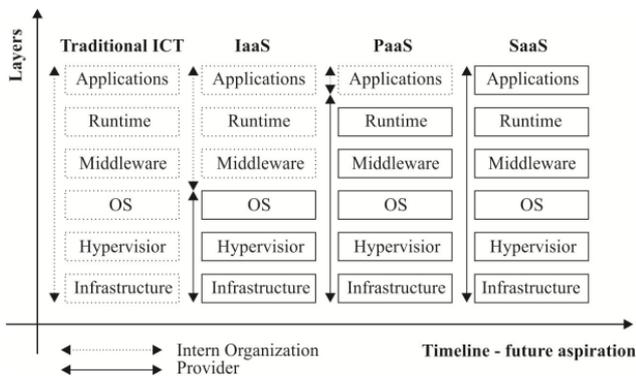


Figure 1. Service models ([8], edited by authors)

Nomenclature of presented layers:

- Infrastructure – a physical layer (servers, processors, storage devices, network);
- Hypervisor – a virtualization layer which provides the virtualized infrastructure resources;
- Operating System (OS) – the operating system which provides the system resources;
- Middleware – supporting software for communication between upper and lower layers;
- Runtime – special environment in which the chosen application is executed;
- Applications – different applications offered to clients.

IaaS (Infrastructure-as-a-Service) is a platform through which businesses can avail equipment in the form of hardware, servers, storage space etc. at pay-per-use service. In this service model, cloud providers offer from physical or virtual machines to

raw storage, firewalls, load balancers and networks [8]. More specifically, the user buys these resources as a fully outsourced service instead of buying servers, software and network equipment [10].

In PaaS (Platform-as-a-service), cloud providers host a computing environment typically including operating system, data base and programming language execution environment, where users develop and deploy applications [11]. Users can rent virtualized servers for running existing applications or developing new ones without the cost and complexity of buying and managing the relating hardware and software [10].

In SaaS (Software-as-a-service) model, cloud providers install and operate application software in the cloud and users access the software various client devices through either a thin client interface, such as web browser or a program interface. The cloud users do not manage the cloud infrastructure and platform on which the application is running but have control over the deployed applications and possibly configuration settings for the application-hosting environment [8].

### 3.3 Deployment models

CC can be run in various deployment models. Which deployment model is used depends on the user requirements and on market availability [9]. There are various divisions, but according to authors five deployment models can be differed (Figure 2).

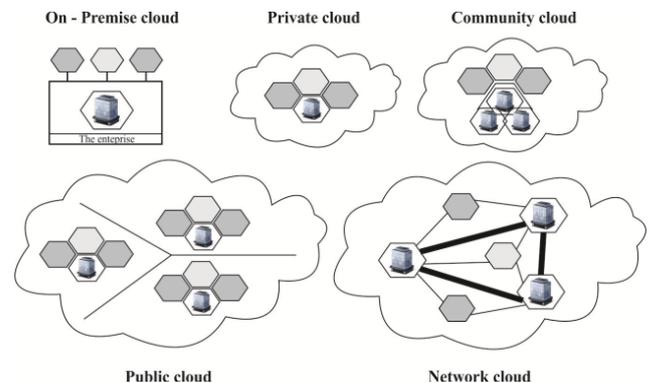


Figure 2. Deployment models ([12], edited by authors)

On-Premise cloud - All services are provided to the client's premises usually by a third-party provider.

Private cloud - The service is used by private clients. A private cloud can be run internally or by a provider.

Community Cloud - The service is used by several members of a defined group. The services may be offered by several providers who are either internal or external to the community.

Public Cloud - The service is available to the public, and in general provided by a single provider.

Network Cloud - Offers a combination of various organization forms, combining their respective advantages and disadvantages.

#### 4. OPPORTUNITIES OF CLOUD COMPUTING IN LOGISTICS

##### 4.1 Data quality in the traditional ICT approach and the cloud approach

In logistics, the right information is essential in order to efficiently realize any process. When introducing modern technologies and various software solutions into logistics branch, significance of the right information becomes priority. High quality data is crucial because every software solution (especially CC) requires quality input values in order to provide quality output values. If data is incomplete or incorrect the most of advanced software systems are useless for decision-making. High quality data must be complete, accurate and time precisiosly.

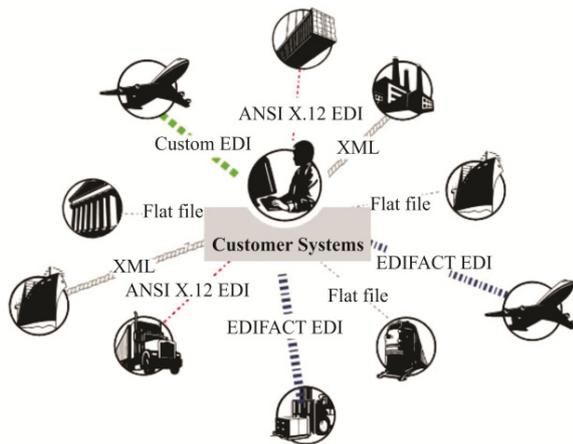


Figure 3. The traditional ICT data network [13]

There are three steps for getting quality logistics data in traditional ICT network [13]:

- 1) Connecting with partners: (a) build ICT infrastructure, (b) determine communication protocols (EDI) (Figure 3).
- 2) Normalizing the data they provide: (a) monitor data flow – dedicated ICT staff, (b) ensure that the data is normalized (locations, currencies, equipment types, organization names, reference codes, charge codes, etc.) – the goal is to avoid confusion.
- 3) Managing data quality: (a) monitoring for accuracy, completeness, and timeliness, (b) efficient ICT team of experts that are able to manage the relationships with partners and to provide missing information.

In opposite, CC offers easier way to establish efficient and effective logistics process which significantly lowers costs and enables time savings. Cloud platform facilitates an on-demand data network. The basic principle of functioning of such network is the following rule: the more clients join the network, the lower costs are achieved. The administrators create and maintain the cloud network and update all the information and crucial data across the network which always offers only actual and topical data to clients. Also, cloud network provides data that is already normalized, reduces time-to-benefit and shifts the hassle and technology risk from client-side to the on-demand network provider (Figure 3) [13].

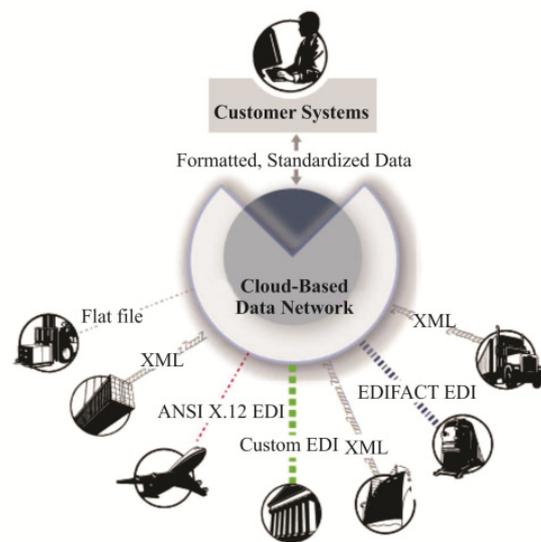


Figure 4. The cloud data network [13]

##### 4.2 Benefits of cloud computing in logistics

The impact of CC in logistics is visible in the three important segments:

- 1) Collaboration – In each logistics process there are large and variable number of participants which is why the collaboration between all entities can be inefficient and even poor. Lack of cooperation between participants and barriers between different ICT solutions in each company are the main reason for emphasizing CC as new form of doing business in logistics. CC offers a common platform for all entities in logistics processes making them interconnected in the network.
- 2) Modernization – Volatility and the unpredictable nature of modern logistics processes encourage the transformation of the traditional logistics organization. The current trend in business is that the most of

logistics processes have variable rather than fixed costs. Therefore, CC provides modernization and enhancement of logistics organization and makes logistics processes more transparent and subject to data quality forecast which later facilitates decision-making process.

- 3) Implementation speed – The most important prerequisite for the CC adoption is wide bandwidth and reliable internet connection. Then, the implementation speed of CC is very high. The most important factor is to form a coherent team of experts from logistics and software fields and to suffice their cooperation.

Benefits and opportunities from the cloud computing adoption in logistics are:

- significant improvements in efficiency;
- increased benefits from faster time-to-value realization;
- single source of a logistics process;
- transparency in communication of all participants in the logistics cloud;

- comprehensive oversight of all processes;
- wide range of solutions;
- different analysis of the high quality data;
- tutorials availability;
- time savings when searching the right information and adequate solution;
- visualization of the entire workflow;
- clarity of the key functionality;
- various solutions for the same problem;
- updated and upgraded applications;
- constantly emerging capabilities;
- data security, etc.

## 5. STATE OF THE ART – WORLD-WIDE CLOUD

The following conceptualization shows in which direction the transformation of future logistics business will be focussed (Figure 5). Although this is just a prediction based on current trend, it is highly feasible in practice. Figure 5 also presents a framework for a world-wide cloud in which quality information flows become the most important.

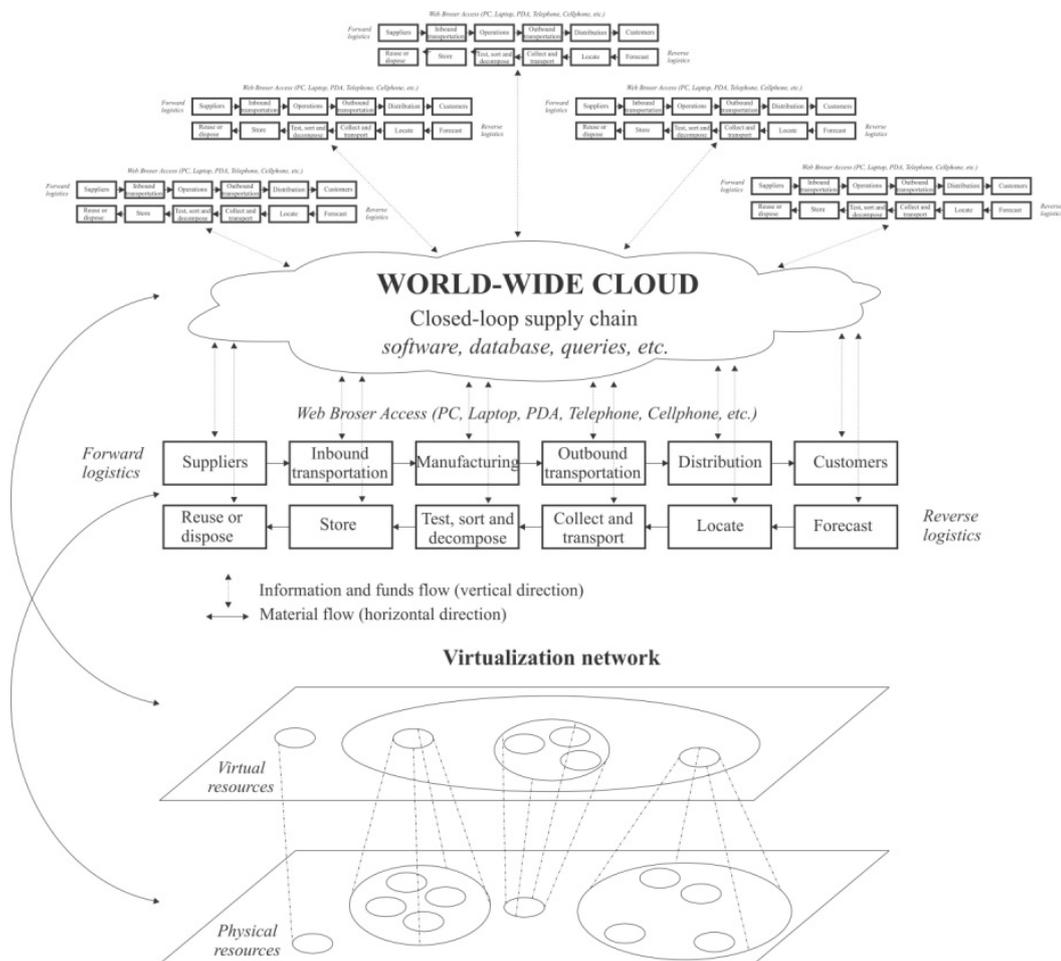


Figure 5. World-wide cloud

## 6. CONCLUSION

ICT unambiguously provides strategic advantages in business for logistics companies. Functioning of logistics processes without ICT support would be insufficient, even impossible. Nevertheless, the constant revolution of ICT sector frequently offers new improved solutions, but also stimulates new conditions for the adoption and reorganization of current business politics.

Cloud computing presents a peak of the ICT impact on logistics. New concept integrates modern technologies, latest software solutions and high quality data into one network. It also reshapes traditionally information flows in which the quality data becomes accessible within few seconds. Material flows cannot be transformed significantly by this system, but cloud approach facilitates and improves its realization. Nobody can for sure say how logistics process will look like for a few years or in which direction it will stream, but for now the future is in the cloud.

## ACKNOWLEDGMENT

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# INFLUENCE OF GPS TECHNOLOGY ON COST CONTROL AND MAINTENANCE OF VEHICLES

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***Abstract:** Quality control of vehicle costs requires the modelling of normed fuel consumption which expresses fuel quantity in regard to tracking indicators such as the engine operation, travelled path length and burden mass, for each unit of vehicles and a certain working task. How much the applied IT technology of satellite navigation, such as the Global Positioning System, can contribute to a reliable determination of effectiveness and efficiency parameters in city logistics systems? Especially for the parameters of vehicle running costs in the waste collection system. This paper gives a software model to determine the normed fuel consumption of the complex waste collection system based on the GPS application and logistics experience. Influence of the tracking parameters on the accurate determination of essential elements to assess the efficiency of process is shown. Also, the paper shows importance of the vehicle electric supply system for the exact calculation of efficiency indicators. The paper indicates advantages and imperfections of a chosen logistics system and how some imperfections can be overcome. Using the software obtained tracking parameters we can make the diagnostic decisions in maintenance and thus perform the quality maintenance management of refuse collection vehicles system.*

***Keywords:** logistics system, tracking parameters, running costs, maintenance, refuse collection.*

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## 1. INTRODUCTION

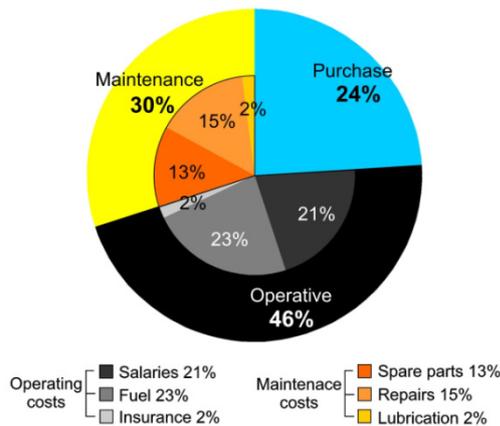
The Global Positioning System (GPS) is universal logistic support for monitoring the moving objects in city logistics systems. It is also in the solid waste management system, especially in the waste collection process where moving objects are the refuse collection vehicles (RCV). GPS tracking parameters also contribute to detect the imperfections of technical systems on vehicles such as the system for battery charging (generator and voltage regulator). GPS diagnostics can be a significant support to a timely implementation of maintenance procedures as well as cost control of vehicles.

Life cycle costs can be generally divided to the purchase costs, running and maintenance costs. According to the research [1], the most important costs of vehicle life cycle are the running or operating costs and they are shown in the example of RCV. The operating costs take almost one half of

total costs (Fig. 1) and they mainly contain the engine fuel costs, insurance and registration costs and costs of workers' salaries. In Fig. 1, one can see that the fuel costs are the most important singular costs after the purchase costs because they take almost a quarter of the total refuse collection vehicle costs. Therefore, the optimal management of running costs, especially fuel costs, is a permanent goal in the realization of efficient working process. The optimization of these costs requires answers to some questions. Which GPS tracking parameters should be chosen for the efficient control of running costs? Does the effective fuel consumption is the optimal one in the same time? How much reliable are the obtained tracking parameters for further use in the cost optimization process?

One aspect of the IT technology application (GPS tracking) is shown in this paper. It is the implementation of reliable key parameters in the vehicle tracking process. Some applications of GPS technology as a tool for vehicle diagnostics are shown also in the paper within several typical case

studies.



**Figure 1. Life cycle costs structure of refuse collection vehicles**

## 2. GPS TRACKING PARAMETERS

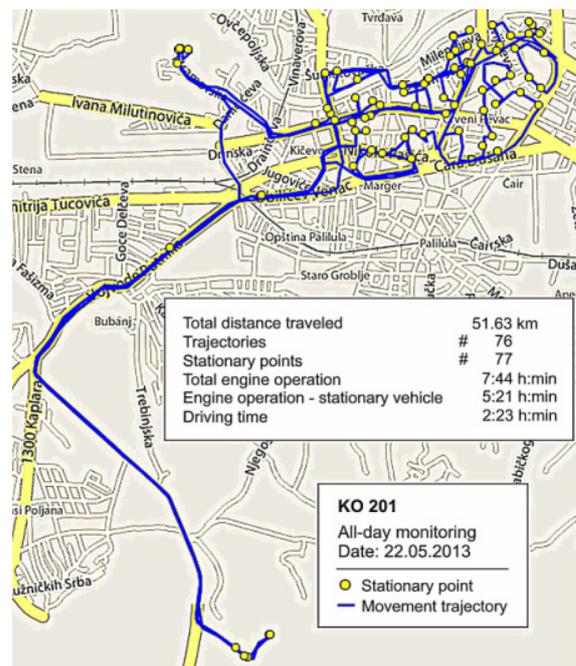
By installing additional sensors/encoders on vehicle, the GPS tracking of parameters such as motor fuel consumption (flow meter), change of fuel level in tank (capacitive sensor), cargo mass in transport or loading (weight sensor), available volume of cargo space (volume encoder) [2] and pressure in hydraulic system (pressure transducer) is enabled. The use of more additional sensors/encoders corresponds to vehicles with a superstructure such as RCV, and it depends on the input-output (I/O) capacity of tracking device.

A significant vehicle fleet efficiency indicator is the motor fuel consumption per quantity unit of transported burden, travelled distance and working hour. In the logistics systems of service activities such as the supply chain system or the waste collection system, a significant efficiency parameter is the fuel consumption per unit of transported goods, raw material, waste and service, [3].

The city logistics systems, such as the waste collection system, are spatially limited most often by size of a city, city quarter or district which implies the use of vehicles with frequent stops and engine operation without moving. Therefore, the indication of fuel consumption per engine-hour corresponds to these logistics systems. The RCV operates most often in the moving regimes with frequent short breaks due to the waste loading. Driving engine uses also for moving the executive devices on vehicle which requires its work during these moving breaks of vehicle. The operating – exploitation fuel consumption depends on objective (engine type, traffic congestion, topography, weather conditions,

etc.) and subjective (vehicle handling, routing) factors. The fuel consumption is an exploitation vehicle parameter which can be variously traced depending on an applied technological solution.

Modern standard measurement of fuel level is performed by transferring signals from the level tank sensor via the controller area network bus (CAN). Accuracy of these standard measuring systems is limited to 90% due to the impossibility of fuel level measurement at the top of tank [4]. A more precise measurement of fuel level in tank, with an error less than 1%, [5], requires the use of capacitive sensor. On the other side, a direct measurement of fuel consumption is based on the measured difference of fuel flow in the intake and return branch. By observing the fuel consumption at time unit and the level state in fuel tank, eventual irregularities (and misuses) in vehicle exploitation can be determined. In the absence of direct measurement with the flow meter, the operating fuel consumption is calculated using the GPS tracking parameters i.e. the distance travelled and engine operating time.



**Figure 2. An all-day route of a refuse collection vehicle**

The distance travelled is measured by odometer and it is a systemic parameter in GPS that is obtained by comparing the current position and initial - previous position (longitude, latitude and altitude) according to the terms of geo-referential mapping. A route of the refuse collection vehicle KO-201 from the vehicle fleet of the company Mediana-Niš, Fig. 2, was obtained by an all-day GPS tracking using software [6]. The total distance

travelled was consisted of 76 elementary trajectories and 77 stationary points. The tracking device Teltonika FM4200 with voltage range of 10÷30 V and max consumption of 250 mA was used in the vehicle tracking process.

The engine operating time (mh – motor hour, engine hour) can be measured using the engine-hour meter (general solution) and GPS (modern solution). The measured engine operating time by software GPS application depends on a global time which is a satellite-measured time and other I/O parameters such as contact, number of crankshaft revolutions and battery voltage. Is the “contact” time identical to the engine operating time? Can it be taken as an accurate engine-hour indicator?

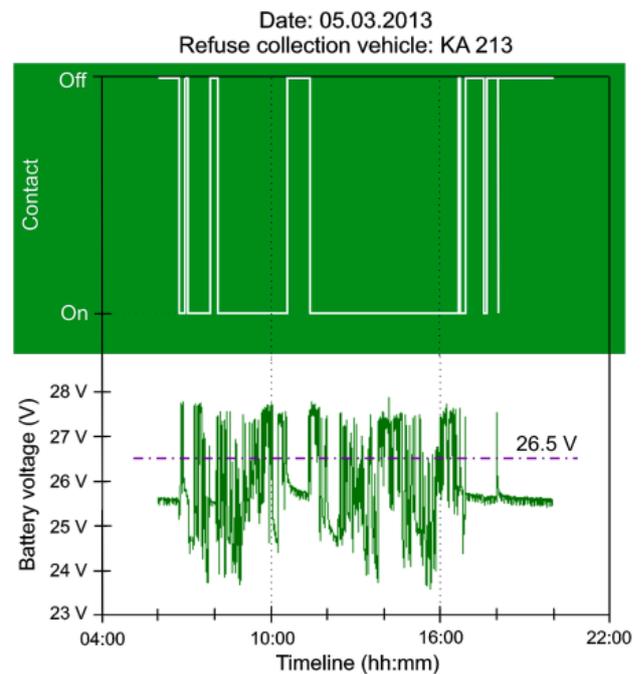
### 3. USE OF GPS DIAGNOSTICS IN VEHICLE MAINTENANCE – CASE STUDIES

The electric power supply system of vehicle is playing an important role in the GPS monitoring so it is necessary its permanent maintenance. A nonconforming unit of the system (generator, voltage regulator, battery) can cause the irregularities to determine the significant parameters of vehicle tracking. Such significant parameter is the battery voltage, which if takes value lower than default, then can lead to the error of engine operating time as well as fuel consumption calculation.

The three case studies of characteristic conformity states of the electric power supply system in vehicle are shown hereinafter. The following diagrams show the time records of tracking parameters change obtained by the GPS technology. In the next diagrams, Fig. 3-5, two each of measurements are shown together, as the measurement of battery voltage change and the measurement of contact state in a given time range. In the same time, these diagrams are the diagnostic tools to detect the irregularities of electric power supply system in vehicle.

In the first example of GPS diagnostics, Fig. 3, an often case of nonconforming system to charge the battery in vehicle – the impulse charging is shown. The battery has alternative charging and discharging which can be cause by nonconformity of some elements of electric power supply system in vehicle. The occurrence of error in the automatic calculation of engine hours is a consequence of the impulse battery charging if the software has a predefined default value of the limit battery voltage. Then, the voltage higher than the limited (e.g. 26.5 V) implies turned on vehicle motor, while the voltage under the

predefined limit indicates turned off engine, Fig. 3 on the below. In the same time, the contact diagram, Fig. 3 above, shows the total engine operating time.



**Figure 3. A problem of impulse battery charging**

This is a good example that two different parameters, the engine contact and battery voltage, can give a significant difference of engine hour values which influences to the calculation of normed fuel consumption. If the analyst dispatcher relies on the total engine operation time of 3 hours, obtained from diagram in Fig. 3 on the below, it will not have a realistic insight to vehicle performance as well as the fuel consumption which will be then significantly higher per unit of time. On the other side, if the contact data is taken, Fig. 3 above, one can see that the operating time of vehicle amounted 8 hours. However, even this data is not completely objective because it may contain the contact time without starting the engine. Nevertheless, the contact time criterion has a much greater precision to calculate the engine operating time in relation to the battery voltage criterion, in this example.

The following example indicated the absence of battery charging during all operating time of vehicle, Fig. 4. Prior the morning starting of engine, the battery unit voltage had a satisfactory value slightly higher than the nominal  $U_n = 24$  V. This data indicated the system conformity. However, the engine starting was not successfully and it required the use of auxiliary methods which caused the expressed impulse battery discharge (area of largest discharge at start up, Fig. 4 on the below).

By observing Fig. 4, one can see that the battery

charging system had nonconformity, at all operating time of the vehicle, which caused the voltage drop in the battery (discharging) even to the value of 10 V, in the area of largest operational discharge. During that time, the contact diagram from Fig. 4 showed the engine operation at voltages lower than the limit. With the reliability aspect, it had a higher probability for the complete battery discharge. If the next measurement will indicate the voltage lower than 12.4 V, which is the limit voltage of lead batteries, then the battery will not be a good further to use.

In the case study from Fig. 4, the preventive maintenance of electrical installation in vehicle was not good, so the unnecessary costs occurred as the consequence of bad decisions in the maintenance. Using the limit voltage method (mentioned voltage of 26.5 V), also according to the voltage diagram from Fig. 4 on the below, here we would not have got the operating engine hours contrary to the contact diagram where we can determine the operating time around 5 hours. The “contact method” was a more reliable method than the “battery voltage method” and in this case.

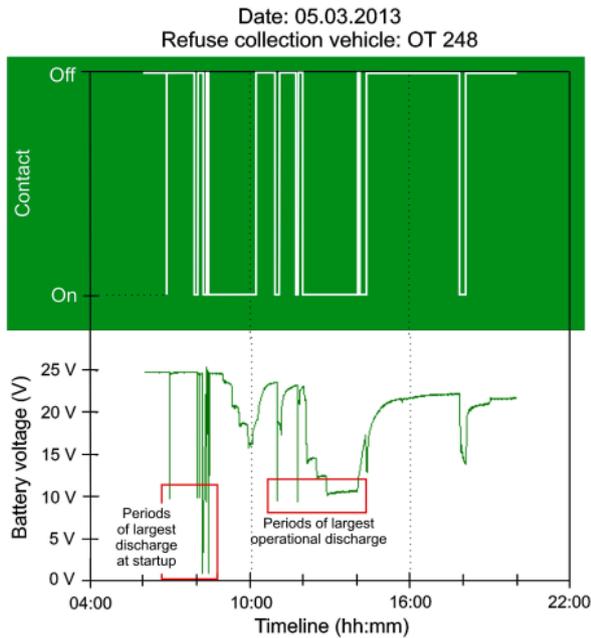


Figure 4. A problem of continuous battery discharge

The superposition of battery charging time and contact on time is clearly seen in Fig. 5 (“voltage” on the below, “contact” above). It speaks that the contact on time is identical to the operating engine time. The electric power supply is stable with small oscillations in the highest voltage area (close to 28.2 V). The battery voltage declines gradually, but it does not exceed below the nominal value i.e.  $U_{\min} = 25.44 > U_n = 24$  V in the idle engine time (contact =

off).

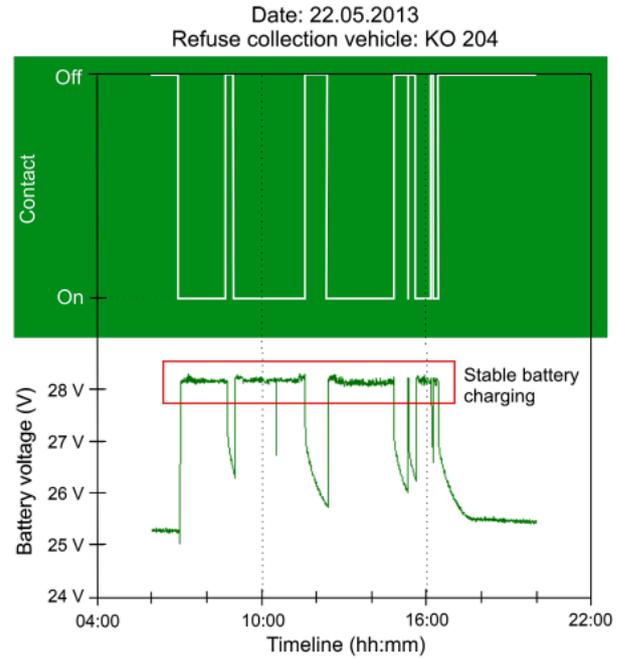


Figure 5. An example of good battery charging system

It can be concluded, from Fig. 5, that the battery structure is quality and allows the predicted range of limit voltages, which means that the battery “keeps” voltage. Therefore, this diagram indicates the complete conformity of system for electric power generation and energy storage in the vehicle. Data about vehicle tracking parameters, obtained using such example, are reliable and they can be unambiguously used to calculate the normed fuel consumption.

#### 4. A MODEL FOR FUEL CONSUMPTION ANALYSIS

Using Eq. (1) to (3), the calculation and comparison of effective and normed fuel consumption, for a selected driver  $d$ , can be theoretically described as:

$$D^d = F^d - N^d, \quad (1)$$

$$F^d = \sum_{k=1}^t \sum_{j=1}^r \sum_{i=1}^p F_{ijk}^d, \quad (2)$$

$$N^d = \sum_{k=1}^t \sum_{j=1}^r \sum_{i=1}^p n_{ij} E_{ijk}^d, \quad (3)$$

where  $D$  is the difference between the realized  $F$  and normed  $N$  fuel consumption in litres per month;  $i$ ,  $j$  and  $k$  are the subscripts that denote respectively the number of vehicles in work “ $i$ ”, the number of working areas - tasks “ $j$ ”, the number of a vehicle

working days per month “*k*”; *n* is the norm of fuel consumption in l/h per vehicle “*i*” and working area “*j*” and *E* is the vehicle operating (effective) time that is obtained using GPS or tachometer record in hours (h).

Here, it should be distinguished from each other the total vehicle working time *W*, which contains the breaks of engine operation, and the vehicle effective time *E* when is the driving motor turned on and the vehicle consumes fuel. The calculated difference *D*, Eq. (1), determines the fuel consumption area i.e. the permissible and non-permissible consumption. If is  $D \leq 0$ , then the fuel consumption is an acceptable consumption. If the difference is within the interval  $0 < D \leq 0.1N$ , then the overspending of fuel is within the tolerance limits. However, if is  $D > 0.1N$ , then the overspending is an unacceptable consumption.

A key parameter in the fuel consumption analysis of RCV is the number of engine hours. A large influence on the accuracy of this parameter obtained by GPS technology has the conformity of electric system in vehicle which is considered in the case studies from Fig. 3-5. Since this conformity state is

changeable, the model for fuel consumption analysis [7] is designed to perform the parallel computation of normed fuel consumption according to the two data groups of engine hours, obtained by the GPS tracking system and tachometer device. Fig. 6 (table) shows a part of the program report for cumulative fuel consumption per driver (matbr) in an observed period, e.g. monthly. The percentage fuel overspending is software determined for both data groups of engine hours e.g. the tachometric (CF\_1) and GPS (CF\_2) data, in relation to the normed values (nor\_tah, nor\_GPS). Of the two obtained percentage values of fuel consumption difference, the lower value (CF\_3) is adopted using software [8]. Thus, the drivers with the negative computed differences had the lower fuel consumptions (✓) than the anticipated one, and they with the positive differences, overspending. In the cases of unacceptable consumption e.g. the difference  $D > 10\%$  (✗), the corrective measures were applied while the difference, marked as “?”, was located in the tolerance field of exceeding.

matbr (PIN - driver)	utr_gor (L)	nor_tah (L)	nor_GPS (L)	CF_1 (%)	CF_2 (%)	CF_3 (%)	
729 SASA PROKIC	165.56	108.23	134.41	52.97	23.18	23.18	✗
781 DRAGAN STEVIC	195.15	145.93	183.62	33.73	6.28	6.28	?
1500 MILIJA RADENKOVIC	217.40	175.94	172.63	23.56	25.93	23.56	✗
1978 MILISA ZIKIC	140.20	141.40	144.95	- 0.85	- 3.28	- 3.28	✓
2076 ZORAN IVANOVIC	148.34	121.00	134.13	22.60	10.59	10.59	✗
2642 SASA CEKIC	129.68	126.93	133.11	2.17	- 2.58	- 2.58	✓

Figure 6. The program report for monthly cumulative fuel consumption

The fuel consumption analysis is an integral program module to control the vehicle exploitation process in the communal system. The original program code of model was generated in software for standard database management [8]. A part of a module algorithm to determine the percentage fuel overspending using the function CF\_1 and CF\_2, and the choice of lower percentage value using the function CF\_3 is shown as follows:

```

select m.sifoj,r.matbr,
nvl(sum(r.utr_gor),0) GOR,
nvl(sum(TO_NUMBER(i.GOR_TAH)),0) nor_tah,
nvl(sum(TO_NUMBER(i.MC_NERADI)),0) nor_GPS

from matrad m,rad_vozila r, izvrsenost i

where m.matbr=r.matbr and r.matbr=i.matbr and
r.konto=i.konto and r.datum=i.datum

and r.datum>=:od and r.datum<=:do

group by m.sifoj,r.matbr

order by m.sifoj,r.matbr
    
```

```

function CF_1Formula return Number is
begin
return ((:gor-:nor_tah):nor_tah)*100;
end;

function CF_2Formula return Number is
begin
return ((:gor-:nor_GPS):nor_GPS)*100;
end;

function CF_3Formula return Number is
begin
if :CF_1>=:CF_2 then
return :CF_2;
elsif :CF_1<:CF_2 then
return :CF_1;
end if;
end;
    
```

## 5. CONCLUSION

GPS technology contributes to better cost control of vehicles – cost reduction. Hence, the monitoring tools should be directed to the precise determination of significant tracking parameters. The accuracy of tracking parameters depends on initial setup of

predefined sizes. For obtaining a satisfactory accuracy of vehicle operation indicator (engine-hour), the electronic measured data of number of crankshaft revolutions should be used there where it is technologically possible. If it is not possible (for vehicles of older generation), then the cross checking method should be used for more (at least two) of the output GPS parameters (contact, battery voltage, etc.).

A tracking system of vehicles provides a required accuracy of tracking parameters under the condition of eliminated nonconformities of items which imply imperfections of system such as the electric and electronic systems in vehicle, most frequent. This can be achieved by permanent preventive maintenance, especially of the system for charging the vehicle battery as well as the system to protect the GPS tracking device against the impulse voltage overload.

The used GPS technology represents a very good diagnostic tool in the maintainer's hands for detecting the irregularities and nonconformities in vehicles. Using graphical reports – diagrams the nonconformities of electric supply system in vehicle can be detected after which timely the corrective and preventive maintenance decisions can be made.

When choosing a GPS technology, it should pay attention to several important factors. The tracking devices with more input-output ports enable the development of monitoring system. By putting in place new sensors/encoders, the system upgrading is enabled. Also, it is necessary to employ a quality and precise software that allows a comfortable work and a large number of reports. If the dispatch centre of logistics services uses such technology, then the advanced training of employees for working with the technology (software, hardware) should be continuously performed.

The developed logistics model of fuel consumption analysis is a suitable model for application in the city logistics systems which use same vehicles to perform a larger number of different work orders. This model corresponds to the communal systems which perform waste collection on a relative small territory with large population (city, municipality, district, city quarter). The model is developed for use in the logistics-dispatch centre

of communal enterprise. The model enables a software support to schedule and analyse the exploitation of vehicles as well as the reporting in all process phases of waste collection (reports: availability of vehicles, implementation of work orders, fuel requisition, GPS tracking parameters, etc.).

## ACKNOWLEDGMENT

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# THE IMPORTANCE AND CHARACTERISTICS OF LOGISTICS IN ELECTRONIC COMMERCE

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***Abstract:** Contemporary trends in globalization and internationalization gives great importance to the logistic system management. Electronic commerce, as a distribution channel in contemporary business conditions, is one of possibilities for gaining competitiveness. Characteristics of logistics in electronic commerce are customized to specific product ordering, inventory management, warehousing, distribution and packaging of products which is delivered. For efficient functioning of electronic commerce it is necessary to have consistent logistic system that will be support for the electronic commerce system through warehousing, inventory, delivering products, and returning the product that is inadequate. Traditional logistics is radically changed with electronic commerce. The essence of electronic commerce has changed the way how logistics functions, which brings new challenges in gaining efficiency of logistic system.*

***Keywords:** logistic system, e-commerce, efficiency, logistic activities.*

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## 1. INTRODUCTION

The role of logistics in e-commerce is to reduce the risk, that arises from the virtual relations, to a minimum. Logistics in e-commerce reduces the risk in the relationship between the seller and the customer, by ensuring that the right product (ordered in a electronic shop), is in the right place (at the consumer's address), at a certain time (the duration which will be acceptable to the customer), and to specific customer in the global market.

One of the main disadvantages of e-commerce is the speed of disposal of the product which does not correspond to the speed of ordering. Namely, the speed of ordering may take a few seconds (or a few "clicks"), but time of disposal of the product is postponed until the delivery of the product, and it can take up to several days. When we talk about logistics in electronic commerce, the question is:

- How long a customer is willing to wait, and under what conditions is willing to wait longer in terms of e-commerce?
- Could logistics, under conditions of e-commerce, be considered as a critical factor of success?

In order to make e-commerce attractive way of buying, it is necessary to provide some competitive advantages to the customer in comparison to other

forms of buying the same product. Also, competitive advantage should overcome the eventual dissatisfaction with the physical unavailability of the product and the risk which customer takes in electronic commerce. Logistics has a key role in overcoming these disadvantages of e-commerce, and in conditions of e-commerce takes on new dimensions.

## 2. THE ESSENCE OF LOGISTICS IN E-COMMERCE

Assumptions of this research should prove a paradigm that every product that is sold in the traditional way can be sold on the Web. That involves integration of the offer, the order process, the payment process and other processes in the online sales with the logistics system, as an important element. In traditional sales, a customer buys a physical manifestation of the product (although it is not used yet), because customer buys the product with the conviction that it serves its purpose, and on the other hand the seller receives equivalent in money for the product. In the virtual world, the subject of the sales relationship is a virtual product and virtual money, and the physical manifestation of the product, its purpose and value, is in charge of logistics. Logistics system, that supports all the characteristics of electronic commerce, needs to provide and maintain a value for

which customer has decided to buy in the electronic way, rather than in the traditional way.

Electronic commerce can be a part of the electronic system in the traditional distribution (the so-called strategy "click and brick") and overall electronic solution ("pure" electronic seller). E-commerce transactions are characterized by the transfer of the product, offering, presentation, ordering and processing orders electronically - on the Internet. Electronic commerce is a revolutionary way to sell products, but also specific way for delivering product to customers. Today, customer who buys online, wants to monitor the ordered products at any time, from the time he clicks the "Buy" button, until the moment when the package arrives at his home, as well as to follow the pack, determine the cost of delivery and split orders to multiple addresses [1].

The most convenient way to perform logistic activities has been based on moving a large amount of units at the same time to the selected consumers in several geographical places. In the traditional logistics the shipment is followed through the container and pallet, not by the individual unit of goods.

With e-commerce, traditional logistics is radically changed. The typical buyer of electronic commerce is unknown entity, who ordered products on an individual basis, based on impulse, seasonal demand, prices, etc. The manufacturer or online seller must be able to adapt to individual order, deliver product directly to the customer anywhere in the world, follow the delivery in the supply chain, answer to customer inquiries, and monitor the return of the product by the customer (reverse logistics). It should also be borne in mind that the users of these logistic services have a much greater expectations, in terms of speed and reliability of delivery, in comparison with the traditional way of buying [10].

### **3. CHARACTERISTICS OF LOGISTIC ACTIVITIES IN ELECTRONIC COMMERCE**

Characteristics of logistics in electronic commerce are evident in every logistic activity. Distribution challenges are reflected in the delivery of several smaller logistics units in different locations, so it is necessary to integrate all aspects of shipment management, multi-modal distribution, monitoring of routes and timing, and management of transit and receiving shipments. Warehousing in electronic commerce implies the existence of warehouse management system, which should enable easier tracking of products in the warehouse

and quickly preparation and sending the ordered products. Procurement system should be integrated so that follows requirements, adequately manages inventory, monitors inventory by accounting inventory, plans the sale, so that the products that have the potential and frequency of purchase are available, and that products which are not purchased do not create additional costs. Adequate documentation in the logistics and management of the delivery process is necessary to provide shipment tracking and recognition of items, and mobile applications should provide shipment tracking for all stakeholders (including customer who purchased the product). The process of reverse logistics includes all mentioned activities in the process of returning the product. The management of this process needs to answer the question what to do with the product that is returned, and find the right solution for the customer that had returned the product.

The main areas of business logistics system include [6]: implementation of orders, inventory, warehousing, transportation and packaging, which have new dimensions in terms of e-commerce. Starting from orders, in electronic commerce, orders are collected electronically, from customers on the website, and sent to realization.

#### **3.1 Implementation of Orders in Electronic Commerce - Electronic Form of Order**

Ordering products in electronic commerce is the first step in this particular complex logistics process. After selection of the product on the website, the customer creates an electronic order which includes personal data such as: name, e-mail address for electronic communication and verification, address for delivering, method of delivery (which will determine the time of disposal of the product), method of payment, contact phone number and similar information. Most electronic stores use authentication, by setting a single question to a potential customer, or printing the order of letters and numbers in a field. Transferring selected products in the electronic basket and confirming payment and delivery, the customer orders the product.

As a confirmation of the created order with the data entered, the customer gets email message that verifies information. The electronic message usually includes confirmation of inserted data, and a username and password of a potential customer. If customer decides to purchase and confirms the conditions of purchase ordering, receives on the same email address electronic form of order or

invoice (if customer has decided to pay by cash on delivery).

### **3.2 Inventory Management in Electronic Commerce**

One of the least explained activities of marketing logistics is planning and inventory management (including in electronic commerce), in an ideal world there would be no need for inventory, because sellers can accurately predict demand, but unfortunately the world is not perfect and the forecasts are not accurate [9]. The complexity of inventory management in e-commerce is reflected in the fact that it is performed in the global market, because the seller can not predict who will be a customer, nor the demand for the product. Seems almost impossible to determine the optimal level of inventory, because the demand for a particular product in one period may be small, while in the future may exceed the available quantities. In this segment it is important to follow demand impulses and respond adequately to changes, so that in case of declining demand there could be easily found a way to sold the amount of inventories (through discounts, sales with a similar product, as a present with the new version of the same product, etc.).

Also, different models and inventory management systems are available to members of the supply chain, based on a constant exchanges of information and joint planning of business operations. Among all models, stands out model called "Collaborative Planning, Forecasting and Replenishment" (CPFR model) [3]. The positive effects of its implementation are reflected in improving the forecasting process (30 to 40%), increasing the level of customer service and sales (15% to 60%) and shorter ordering cycles (from 15% to 20%) [5].

### **3.3 Warehouse Management in Electronic Commerce – Operation of Distribution Center**

E-commerce logistics system includes offices, centers for consolidation of orders and sending ordered goods, warehouses, customer service and software development centers. Depending on the organization of electronic sales, electronic sellers have consolidated some functions, such as storage location and unifying orders, and so on. Centers for sending the ordered goods are usually located near the airport. These centers include adequate storage space.

The warehouse of electronic seller has a single central computer that collects information on the location of the goods and trail maps. Each employee handles PDA device that controls the condition and

location of the goods in the warehouse. During one day of work in the warehouse of one of the global electronic sellers, an employee can exceed more than 10 miles per day in the affairs of placement and distribution of goods. The common practice of electronic sellers is hiring a part-time workers in distribution centers, and thus lower labor costs.

### **3.4 The Role of Distribution in Electronic Commerce**

The role of distribution in e-commerce is reflected in the transmission of the ordered product to the place of delivery specified by the customer. Transportation in electronic commerce is primarily related to the delivery of ordered products to the customer's address. The distribution channel has some changes under the influence of a large number of smaller units of delivery for transportation, and dispersion of individual orders. Customers in electronic commerce are setting new requirements for the distribution of products, such as shipment tracking during delivery. Therefore, it is necessary to provide a higher level of service in terms of availability of information and speed of delivery.

Changes in the distribution of products in electronic commerce are also under the influence of the type of product that is ordered, so [8]:

- For some products, there is no physical distribution (such as digital products, software, digital content, information, etc.);
- For many products that can be ordered electronically there is already physical distribution (eg. ordered books are distributed through the existing fast delivery service to home address by post, products like appliances have traditional distribution network for delivering to home address), and
- For some products there is no physical distribution channel, and it is necessary to develop new modes of transportation and delivery (eg. delivery of general merchandise and groceries requires a completely new means of transportation that would not compromise the quality and freshness of the product).

According to some studies the distribution sector has been identified as the biggest obstacles to further development of e-commerce [2]. According to the study by Anderson Consulting, six of the 10 most common problems in an online selling is associated with the delivery of the product [7]. The biggest challenge remains to deliver general merchandise and groceries (with the range which consists of 10-25,000 products, and includes three temperature

zones) where the order must be implemented within 12 to 24 hours.

### 3.5 The Role of Packaging in Electronic Commerce

Packaging in electronic commerce is primarily concerned with the preservation of products during shipping and delivering the product to the customer, and partly on the product packaging in stocks. When we talk about the packaging of the product during shipping, there are three main aspects of packaging, such as [4]:

- Protection - helps to protect against damages during transport and transit;
- Presentation - gives the first impression of the product, and
- The cost of packaging – has influence on the decision on the type of transport.

The decision on packaging involves assessing which of these functions of packaging is more important for electronic seller and the customer. On the one hand, it is necessary to take into account the damage that may occur during transportation of the product, on the other hand, there are costs that would result in an additional packaging and protective packaging. It is necessary to take into account how the product is packed, how will be manipulated and from what needs to be protected in the manipulation. Packets, sent to the customer in electronic commerce, are usually small and very light. Very easy packs are easily manipulated, it might be expected that products in them could be damaged in handling, so it is necessary to have adequate protection. If the packet of product is sent out of the country, it can be assumed that it will change means of transport, which increases the likelihood of falling, the impact of weather conditions, moisture and other external factors, from which the product must be protected.

### 4. CONCLUSION

Traditional logistics is radically changed in conditions of electronic commerce. Logistics system, that has and supports all characteristics of electronic commerce, needs to provide and maintain a value for which customer has decided to buy in the electronic way, rather than in the traditional way. It should also be borne in mind that the users of logistic services in electronic commerce have a much greater expectations, in terms of speed and reliability of delivery. All logistic activities applied in electronic commerce environment need to be adjusted to special needs of this complex way of buying. In that way, it is essential to be considered, that all specific logistic activities take different principles of functioning in terms of electronic commerce.

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# THE USE OF ICT IN SUPPORT OF PUBLIC ADMINISTRATION TO THE DEVELOPMENT OF LOGISTICS

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***Abstract:** Development of logistics in transition countries has to be supported by public administration which must increase awareness of logistics' importance to the general country development. Available tool is implementation of information telecommunication technologies (ICT). Not only application of ICT technologies to logistics systems is important, but the use of ICT to improve visibility of logistics is significant. Financing of logistics' centres is the base of their function. New financing model, the use of public private partnership (PPP) offers new capabilities. Incoming domestic and foreign investors must have approach to data about present state and future plans of logistics' centres which make them attractive for financing. First insight could be performed through interactive maps of logistics' potential attached on public administration sites. The paper presents activities to create an interactive logistics' potential site performed at Secretary for economy of Government of Vojvodina and proposes new multimedia means for logistics' promotion.*

**Keywords:** multimedia, logistics potential, interactive map.

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## 1. INTRODUCTION

Information communication technology is recognized as an important tool in the global economy of today. Internet, as global computers' network is a base of global flow of information, messages and communications. Flow of goods is closely linked with information interchanges. This makes logistics a parallel process to the global information flow and strictly dependent on ICT.

There are more components of ICT connected to logistics, like shown in Figure 1:

-ICT involved into the core logistics activities, **goods flow** (IRFD, Video surveillance...)

-ICT in logistics **information flows** (database, handling with databases, interchange of data)

-ICT which supports **customers** (websites, social networks, blogs...)

-ICT in the process of **long life learning** for:

- employees and
- services consumers

-ICT as tool for general increase of **awareness** of logistics importance.

From given above follows that ICT has different tasks in logistics systems.

This paper refers to the role of ICT during first and the most important phase of establishing logistics system process. This first phase is task of the political system to recognize and support introduction and strengthening of logistics within other socio-economic systems in society. Innovative ideas in new products should shape the life cycle of a company according to changeable external demands. Companies will stay profitless if the logistics does not follow their activities. Awareness of logistics should be increased on different levels. These levels refer to companies', local, regional, national and international-global area.

This paper presents a project elaborated by support of the Secretary for economy of Vojvodina which objective was to find method to involve public administration into improvement of logistics' importance visibility. Authors contribution is a solution elaborated by the use of multimedia communication platform. Interactive and attractive logistics multimedia map was an outcome of the project. It gives a good public promotion of logistics'

current state, needs and future plans through media. Interest and use of provided ICT tool by stakeholders is significant and their reaction shows indisputable value of implemented technology.

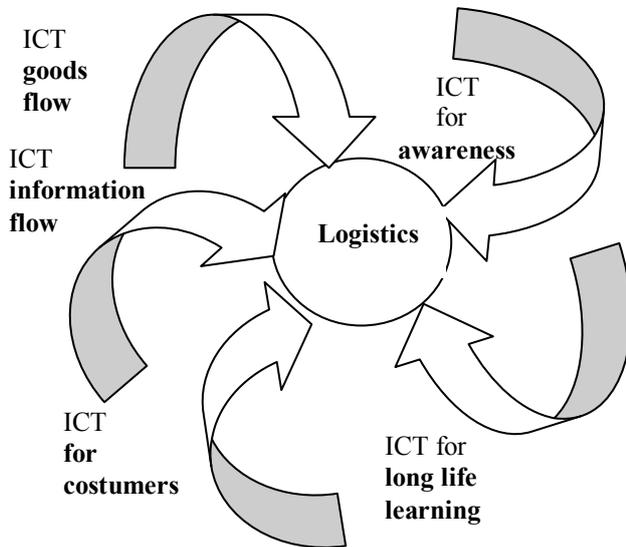


Figure 1. Components of ICT in logistics

## 2. LITERATURE REVIEW

Logistics is even according to its definition “transaction oriented”. This results in fast exchange of information, appearance of lot of new information and data, involvement of new types of database, permanent filling of database, often analysis of database and continuous monitoring and corrections. Number of transactions and operations is big. This implies that logistics is very dependent on ICT [6].

Very important component of supply chain management is ICT, since “no product flows, until information flows”. ICT is “global nervous system” which is linking suppliers with costumers. ICT is a platform to implement “green logistics” systems which by use of multimedia ICT succeed to protect environment and support sustainable logistics activities [4].

Effective use of ICT into logistics assumes integration of logistics process participants. For example, shippers request integration with their suppliers.... Integration demands adequate training process which is dependent of appropriate training polices. The use of ICT tools requests good knowledge and skills [2].

Some authors refer to the new intermediately organization with ICT as their core activities which set up “virtual business webs”. Such way of Internet use creates new values to customers and stakeholders [9].

Authors distinguish “soft” and “hard” part of ICT but consider both as the same important. “Soft” part refers to information management, ability to assess the economic, organizational and technical feasibility, business, communication and design, the development of information systems, their maintenance... “Hard” part refers to software engineering and implementation of technical infrastructure [10], [1].

Some authors consider that the awareness of ICT as a success factor for logistics is evident. But, there is a low level of ICT adoption with particular reference to the Internet and e-business tools [2]. ICT platform as an e-business tool for the development of logistics must be included particularly into logistics' promotion and training of logistics' experts in transition countries [8]. This must not be theory, ICT system within logistics system should be practice, regularly way of logistics' functioning [12].

Information technology trends turn to be very intensive and powerful and will intensively influence logistics future [3], [5].

Web site design is discussed and detailed elaborated by some authors and stressed as powerful promotional tool which can be used in deferent sectors and logistics, too [11], [7].

## 3. PUBLIC ADMINISTRATION AS AN INFO MEDIATOR

The whole project which was performed is consequence of the strong need to attract domestic and foreign investors and to activate economic development of Vojvodina. The need is recognized by the Government of Vojvodina who imposed realization of a project which would make logistics' information and data available for use. Logistics' data should be offered to investors, big companies, SMEs, experts, researchers, professors, students and pupils. Public administration took role of info mediator which would offer data and focus all stakeholders to the importance of logistics as a system which is usually subsystem of many socio-economic systems.

- General objective of the project is:  
To increase awareness of logistics' importance and to attract investments into this sector.
- Specific objective of the project:  
To collect, organize, present and make available to all stakeholders, important logistics' information of the Autonomous Province of Vojvodina.

- Methodology (presented in Table 1):
  - Phase 1 - preliminary activities:
    - (These actions were performed by logistics' experts and were directed towards creation of valid data base structure)
    - selection of factors which determinate the most important logistic centres of the Vojvodina region
    - selection of the most important logistics' centres of the Vojvodina region
    - selection of the cluster of logistics' information which are representative for a logistics centre
  - Phase 2 - collection activities:
    - (These actions were performed by logistics operationals who collected right data already defined in the preliminary phase)
    - collection of data as defined within the preliminary phase
  - Phase 3 – presentation activities:
    - (These actions were performed by external ICT experts who created concept of interactive logistics map and entered collected data)
    - creation of the interactive logistics map concept and collected data entry
  - Phase 4 - Web activities:
    - (These actions were performed by internal ICT experts from public administration who included new interactive logistics map into the existing web portal of the Secretary for economy which was investor of the whole project)
    - Fitting the new interactive logistics map to the existing web portal

**Table 1. Phases of interactive logistics map creation**

Phase	Description	Responsibility
1	Creation of valid data base structure	Logistics experts
2	Collection of logistics data	Logistics operationals
3	Creation of the interactive logistics map concept and collected data entry	External ICT experts
4	Fitting the new interactive logistics map to the existing web portal	Internal ICT experts

- Target groups: Investors, big companies, SMEs, experts, researchers, professors, students and pupils
- Multiplying effect: Spreading the created ICT tool to other logistics and non logistics areas.

### 3.1 Phase 1 - preliminary activities

In the first phase experts selected factors which are of the biggest importance for selection of the

most important logistics centres of Vojvodina region.

The main criteria for rating the logistics centres are agreed as following:

- Position nearby the Danube river
- Position on the railway line

Additional conditions are:

- Nearness of high and main roads
- Transport, water, sanitation and communication infrastructure
- Warehouse facilities

As a result of previous carefully selected factors, there were chosen the following logistic centres, as important:

1. Novi Sad
2. Pančevo
3. West Bačka (Odžaci, Bogojevo, Apatin, Sombor)
4. Subotica-Senta
5. Srem (Inđija, Stara Pazova, Ruma, Sremska Mitrovica)
6. Middle Bačka (Vrbas)
7. Zrenjanin-Vršac
8. Kikinda

Data which are declared as representative are:

- Surface
- Ownership (public, private)
- Urban planning documentation (general, detailed plans)
- Transport infrastructure (nearness, existence and quality of railway, main roads, regional and local roads)
- Nearness of a port (type of the port, quay length, handling capacity, warehouse capacity and type, additional services)
- Warehouse capacity and type
- Development plans and demands
- Additional information

### 3.2 Phase 2 - collection activities

In this phase was clear what kind of data should be collected. Collection was made by sending email with specific table that should be filled in.

### 3.3 Phase 3 – presentation activities

External ICT experts selected adequate ICT software and created core of the interactive map according to description and request made by logistics professionals what is a good example of cooperative work of experts of both sectors. External experts entered collected data, too. Software which was evaluated as suitable was Adobe InDesign CS5. It is the most robust professional document-creation

tool on the market, an ideal platform for creating rich interactive documents. These documents can be navigable, enhanced versions of existing materials (catalogs, brochures, promotions, and so on), or they can be created as original interactive pieces that are never destined for print. Creating interactive documents, presentations, and prototypes in InDesign gives designers the control over format and typography they demand, in the application with which they're most familiar, but with enhancements like slide shows, button navigation, video, live hyperlinks, and more.

**3.4 Phase 4 - Web activities**

Internal ICT experts, employed at the Secretary for economy (public administration) who are in charge of maintenance of the Secretary's web site, incorporated new interactive logistics map into the existing web portal of the Secretary which was investor of the whole project. Web site address of the site which offers interactive logistics map of Vojvodina in Serbian and English languages is: [http://www.spriv.vojvodina.gov.rs/images/flash/Map\\_Serbian.swf](http://www.spriv.vojvodina.gov.rs/images/flash/Map_Serbian.swf).

**4. INTERACTIVE MAP OF LOGISTICS POTENTIAL OF VOJVODINA**

The map consists of (Figures: 2, 3, 4):

1. General data about Vojvodina region (geography, demography, economy)
2. Map which shoes position of Serbia in Europe and position of the Autonomous Province of Vojvodina in Serbia
3. Gravitation zone of Novi Sad as regional center and gravitation zone of each selected logistics centre
4. Map of railway tracks (main tracks, regional and local tracks with their maximum speeds and axial pressures)
5. Map of roads (main, regional, local roads with their lengths)
6. Map of rivers and channels
7. Map of the most important logistics centres
8. Map of small logistics centres
9. Map of ports with description of ports facilities

**I Map of the most important logistics centres**

When a logistics centre is selected, all relevant data appear like: surface, ownership, nearness of transport infrastructure, existing communal infrastructure, urban spatial plans, future plans. Photos are imposed to present current situation and

future urban plans. There is a coat of arms of the town, its representative photo and web site.

**II Map of small logistics centres (which have given their data)**

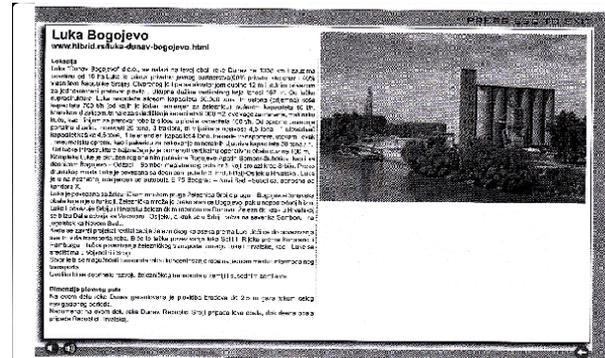
When a small logistics centre is selected, all relevant data appear like: surface, ownership, nearness of transport infrastructure, existing communal infrastructure, urban spatial plans, future plans. There is a coat of arms of the town, its representative photo and web site.

**III Map of ports**

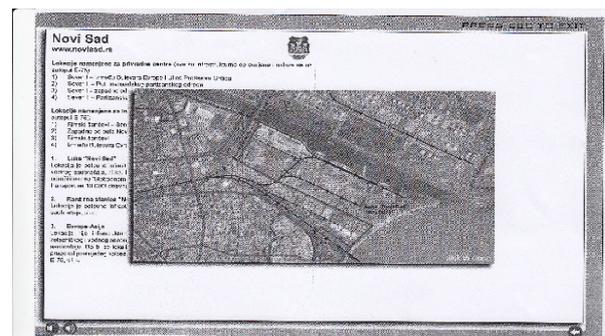
When a port is selected, all relevant data appear like: key length, ownership status, handling capacities, volume of handling, warehouse facilities, additional equipments and services, future plans, needs and demands.



**Figure 2. Interactive multimedia map - first screen**



**Figure 3. Interactive multimedia map – Port of Bogojevo**



**Figure 4. Interactive multimedia map – Logistics centre Novi Sad**

## 5. AWARENESS OF LOGISTICS POTENTIAL IMPORTANCE

The whole process of interactive logistics map creation was initiated by the Council for logistics of the Vojvodina government. The Council consists of logistics experts: university professors and professionals from this area (from shipping companies, ports...). It is coupling of science, economy and public administration representatives what gave remarkable results.

Initiative was welcomed by the Secretary staff who supported the proposed idea. Even this resulted with significant increase of importance of area of logistics within public administration.

After finishing the map, there were organized few promotions which were accompanied with media reports and big interest of media related to the general tasks and goals of logistics sector. It showed that knowledge about logistics was missing.

The use of the interactive map of logistics potential of Vojvodina started with lot of comments. The small logistics centres which were missing from the map requested to be included into the map, too, and this was the next task, already done.

Investors are collecting information and addressing to the logistics entities directly. Results of their further activities will be recognized in the near future.

## 6. CONCLUSION

The paper refers to a good example of ICT technology use in area of logistics sector promotion. This is specially important for transition countries which are under developed in this area and due to the fact that logistics is the final link in the chain of value creation within an economy (in a company, region, country and globally). Applications of IT technologies to logistics systems could be within various processes. Authors describe ICT use during a very important phase of: logistics promotion. This phase of raising awareness about importance of logistics sector consists the most of activities which focus on importance of: education, improving knowledge and skills in this area. Process must have significant support of public administration. It must

seriously prepare and elaborate promotional role for logistics as a source of big value added service .

## ACKNOWLEDGMENT

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**Part III**

**LOGISTICS CONCEPTS AND STRATEGIES**

# CITY LOGISTICS IN THE MONTENEGRIN COASTAL REGION

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**Abstract:** The subject of research in this work is logistics flows and systems in the Montenegrin coastal region as a unique geographical area in the south west part of Montenegro. The research presented in this article is based on systematic approach and its objective is forming the basis for designing a new solution of logistic concept for the agglomeration in question. The newly developed concept is designed to facilitate overcoming of numerous currently occurring problems regarding logistics and to enable realization of total optimization of regional logistic processes and making necessary postulates for improved design, organisation, realisation and control of all logistic processes and systems in the region.

**Keywords:** City logistics, concept, flows.

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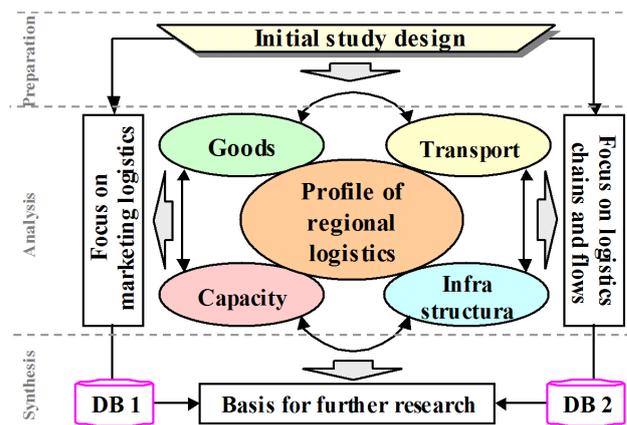
## 1. INTRODUCTION

The urbanization of the Montenegrin coastal region (MCR) is taking place at an accelerating rate thus creating large number of problems. Higher flows of traffic in the area, which are unavoidable during periods of urbanization, is placing pressure on the existing traffic network, leading to time losses, traffic jams, higher pollution rate owing to emissions of harmful gases, and higher level of noise and vibration caused by freight vehicles. All these information to initiate the research aimed at elaboration of a programme designed to spur development of sustainable *logistic concept* (LC) for this region, with orientation to quality of logistic service complying with ecologic and economic principles.

The level of awareness of distinctly articulated needs for overcoming numerous problematic areas related to regional logistics, unorganized and random development of logistics in the area of MCR with addition of a series of accompanying negative impacts as well as the fact that logistics in this region was not entirely and integrally analysed in previous period created strong motives for defining the objective of the research – *defining integrated logistic profile of the region*.

## 2. METHODOLOGICAL APPROACH TO RESEARCH

Research of the logistic profiles is a complex and complicated process. The research process itself for the region in question is based on systematic approach (Figure 1).



**Figure 1. Approach to research**

To gain realistic data, the authors conducted investigation which comprises: (i) physical counting of generators on the entire area of the region, and (ii) opinion research of the subjects involved in regional logistics.

### 3. RESULTS OF RESEARCH

In order to effectively analyse and present basic characteristics of logistics flows in the following units of this work, all generators of logistics demands needed to be divided into groups according to specific economic activities including [2]: generators for regional industry - **G1**, generators for construction - **G2**, generators for retail - **G3**, generators for hotels and catering - **G4**, other generators - **G5**. Defined groups of generators were observed for two specific periods: (i) Off-season period of 273 days; (ii) Season period of 92 days.

The generators of logistics demands on MCR were represented by [2]: (i) 2,503 generators during the off-season; (ii) 3,485 generators during season. Each generator of logistics demands presents a subsystem of marketing logistics of the region with different characteristics of the demand. In order to have a better understanding of the facts, both specific period generators of logistics demands are grouped into 26 distinctive groups.

Hotels and restaurants are the most common demand factor when it comes to traveling off-season (23.61%) and during season (29.38%). In addition to this group of generators there are grocery stores, and they participate in the overall structure of generators with 21.53% during off-season period and 18.45% in the peak of tourist season. These two groups make up almost half of generators of the total number of generators during off-season (45.15%) and in the peak of tourist season (47.83%). This indicates that hotel industry and trade are dominant activities in the region.

Results of done analysis viewed from the aspect of marketing logistics show that:

- 1) 30% of generators have a low share of the total storage space of facilities (as in Figure 2);
- 2) Facilities with food products have a storage area behind the retail section of the building. Moreover in more than 90% of cases associated with adequate space built for a delivery vehicle, so the goods does not pass through sales part in the process unloading the delivery vans.
- 3) There is greater interest from potential buyers in smaller facilities, as evidenced by the fact that more than 70% of the buildings have an area of less than 50m<sup>2</sup>.

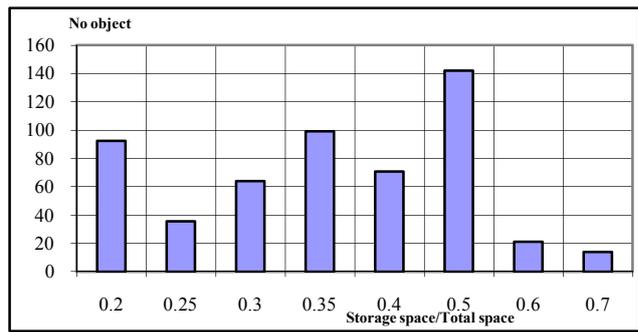


Figure 2. Participation storage in object [2]

- 4) 2,503 observed generators of logistics requirements during off-season use an average of 3,392.8 road freight vehicles [2] of different capacities per day. Most transport requirements have generators in Bar with average 986.9 requests per day, which represents 29.09% of the total number of transport requests in the observed region.
- 5) 3,485 observed generators of logistics requirements during the season use an average of 7,354.4 road freight vehicles of different capacities per day, which represents a 116.76% increase in the number of delivery vehicles compared to off-season period.
- 6) Facilities with food products during off-season period use on average 1,058.9 delivery vehicles per day or 31.21% of the total number (3,392.8) of vehicles in this period [2]. During the season, food facilities move on average 2,201.1 delivery vehicles per day or 29.93% of the total number of these vehicles in this period.
- 7) Hotels and restaurants in off-season, on average use 956.8 vehicles per day, or 28.20% of the total number of this period. Regarding season period, these facilities run on average 2,971 vehicles per day, representing 40.39% of the total number of vehicles for this period.
- 8) Craft shops in off-season run on average 227.2 vehicles per day, or 6.7% of the total vehicle's moves for this period. Regarding off-season period, these generators run on average about 360 vehicles, or 4.87% of the total number of movements for this period;
- 9) The minimum requirements to run vehicles during off-season are attributed to bookstores 2.6 starts per day or 0.08%, followed by furniture shops 3.2 starts which is 0.09% of all starts per day. These generators also have minimum requirements during the season as well. The average annual number of vehicles runnings per capita during off-season is 9.12,

while the average annual number of vehicles runnings per km<sup>2</sup> is 778,36.

- 10) In overall structure of commercial delivery vehicles during off-season major presence have delivery vehicles with the capacity of 1.5 t - 3t with a share of 32.1%, while the share of vehicles with carrying capacity up to 1.5t is 26.6%, vehicles with capacity from 3t to 7t is 16.3% and vehicles with a carrying capacity over 7t is 8.4%. This structure can be interpreted as a consequence of the presence of a large number of small facilities, which in most cases to deliver the goods use their own vehicles;
- 11) In overall structure of commercial delivery vehicles (Figure 3) during the off-season major presence has delivery vehicles with the capacity of 1,5 t - 3t with a share of 32,1%, while the share of vehicles carrying capacity up to 1,5t is 26,6%, vehicles capacity from 3t to 7t is 16,3% and vehicles with a carrying capacity exceeding 7t is 8,4%. This structure can be interpreted as a consequence of the presence of a large number of small objects, which in most cases to deliver the goods use their own vehicles;

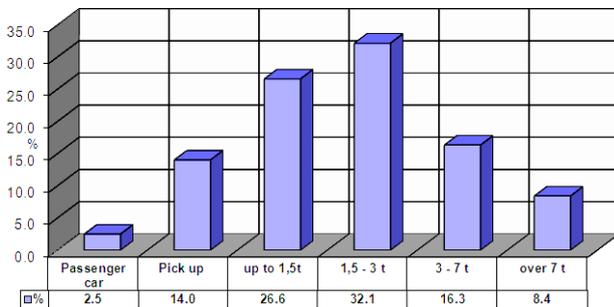


Figure 3. Capacity of delivery vehicles - off-season [2]

- 12) carrying capacity up to 1.5t is 26.6%, vehicles with capacity from 3t to 7t is 16.3% and vehicles with a carrying capacity over 7t is 8.4%;
- 13) In overall structure of delivery vehicles during summer season, the highest representation have vehicles with carrying capacity up to 1.5t with the share of 32.1%, followed by vehicles with capacity from 1.5t to 3t with 31.7%, then vehicles from 3t to 7t with 15% and vehicles with a payload over 7t accounted for 5.7% in total structure;
- 14) The total retention time of vehicles in off-season is 163,453.8 minutes per day, or 48.17 minutes per vehicle, with a large number of vehicles taking up to 35 minutes to unloading;
- 15) During the season, the total waiting time of all vehicles is 46,4426.8 minutes, or 63.01

min/vehicle, which represents a difference of 300,973 minutes per vehicle, with a large number of vehicles taking up to 35 minutes to unloading. waiting biggest reasons are: (i) the number of vehicles on the road, (ii) the profile view, and (iii) the number of requests for delivery;

- 16) In off-season 539 stores with foodstuffs used 1,058.9 vehicles/day, or 21.53%, while the first four groups of generators with 549 facilities, used 42.04 vehicles/day or 1.24%. The largest number of generators (Figure 8) required 1.5 deliveries/day;

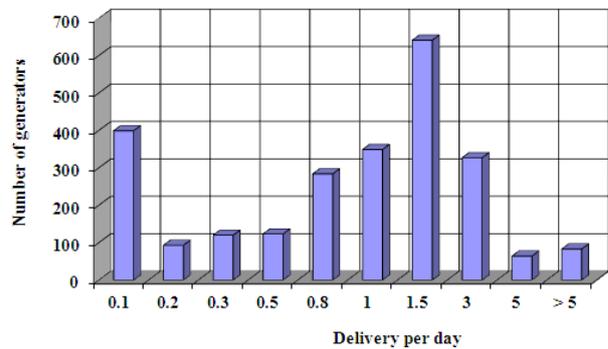


Figure 4. Objects in the generation of requests off season

- 17) Generators during the season used an average of 7,354.4 vehicles/day, or +116.76% compared to off-season. The largest number of generators (Figure 5) required 3 deliveries per day;

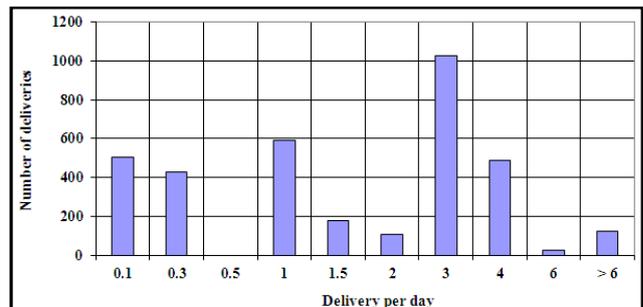


Figure 5. Objects in the generation of requests - season

- 18) Size of delivery per generator is between 0.5t and 0.7m<sup>3</sup>. Weight of the package usually varied between 20 and 50kg;
- 19) Retail food stores in 90% of cases have their own delivery vehicles, and 30% have vehicles with different capacities;
- 20) Unloading goods involves two manual workers in 70% of cases, three workers in 10% of cases, and more than three workers in 20% of cases;
- 21) In 60% of cases goods are being unloaded by hand, or in 40% of cases by hand carts and pallet trucks;

- 22) In 30% of cases, goods are ordered only in writing, and in 50% of cases both in writing and by phone, and in 20% of cases only by phone;
- 23) In 10% of cases there is a positive opinion about the night supply of goods.

About 72% of transported goods is carried out starting with a large number of runs of freight vehicles, while the remaining quantity of goods (about 28%) generates a small number of requirements for runs of freight vehicles.

### 3.1 Logistics flows for regional industry – G1

The industry in the MCR generated 44,779t of goods (as in Figure 6).

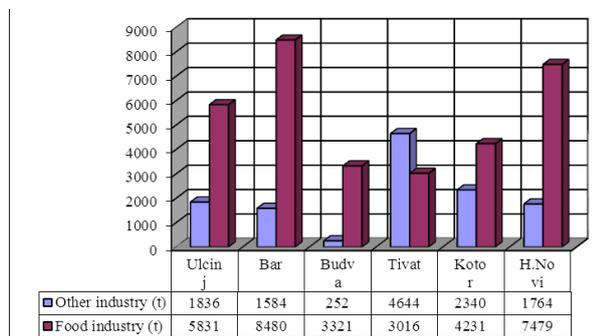


Figure 6. Flows for the industry per city [2]

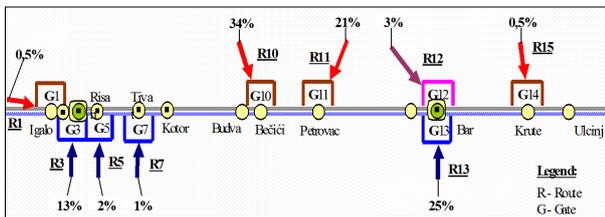


Figure 7. G1 - Goods flows [2]

Table 1. G1 - Transport facilities (%)

Type of transport facility	Direction of delivery of goods for the industry (R – Route)									
	R <sub>1</sub>	R <sub>3</sub>	R <sub>5</sub>	R <sub>7</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>	R <sub>15</sub>	
Car & pick up	-	-	-	-	-	-	-	-	-	-
Van	-	-	-	2	2	-	-	-	90	-
Van up to 3,5t	-	-	-	3	3	-	-	-	10	-
Van over 3,5 – 7t	15	-	-	-	10	10	-	-	-	-
Van over 7t	80	-	-	-	85	85	-	-	-	-
Wagon	-	-	-	-	-	-	100	-	-	-
Ship	-	100	100	100	-	-	-	-	100	-
Airplane	-	-	-	-	-	-	-	-	-	-

Table 2. G1 - Frequency of transport facilities (number)

Type of transport facility	Direction of delivery of goods for the industry (R – Route)									
	R <sub>1</sub>	R <sub>3</sub>	R <sub>5</sub>	R <sub>7</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>	R <sub>15</sub>	
Car & pick up	-	-	-	-	-	-	-	-	-	-
Van	-	-	-	-	203	122	-	-	365	-
Van up to 3,5t	44	-	-	-	183	110	-	-	120	-
Van over 3,5 – 7t	65	-	-	-	305	183	-	-	-	-
Van over 7t	145	-	-	-	1,078	647	-	-	-	-
Wagon	-	-	-	-	-	-	135	-	-	-
Ship	-	5	1	2	-	-	-	7	-	-
Airplane	-	-	-	-	-	-	-	-	-	-
<b>TOTAL</b>	<b>254</b>	<b>5</b>	<b>1</b>	<b>2</b>	<b>1,769</b>	<b>1,062</b>	<b>135</b>	<b>7</b>	<b>485</b>	

The needs of industry according to characteristics and representation of certain manufacturing activities are divided into two groups: the food industry with a share of 72.26%, and for the rest of the industry with a share of 27.74%. Regarding goods flows, 59% of goods flows (Figure 7) were implemented by land routes, and 41% by water routes.

### 3.2 Logistics flows for the construction - G2

Regional generators related to construction in the region of the MCR [2] have generated 154,004t of goods (as in Figure 8).

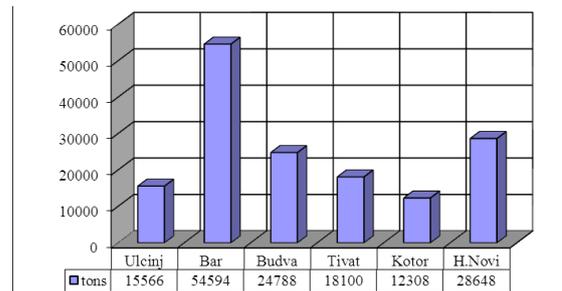


Figure 8. Flows for the construction per city [2]

Regarding the directions, 21.82% of goods flows (as in Figure 9) were implemented by land routes, and 78.18% by water routes.

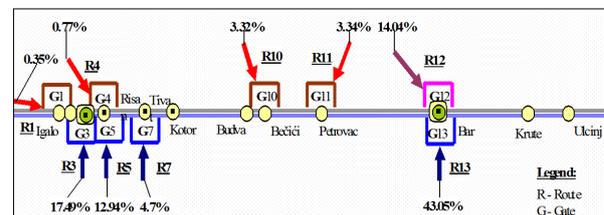


Figure 9. G2 - Goods flows [2]

Table 3. G2 - Transport facilities (%)

Type of transport facility	Direction of delivery of goods for the construction (R – Route)									
	R <sub>1</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	R <sub>7</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>	
Car & pick up	-	-	-	-	-	-	-	-	-	-
Van	-	-	-	-	-	-	-	-	-	-
Van up to 3,5t	3	-	2	-	-	3	3	-	-	-
Van over 3,5 – 7t	7	-	13	-	-	10	9	-	-	-
Van over 7t	90	-	85	-	-	87	88	-	-	-
Wagon	-	-	-	-	-	-	-	100	-	-
Ship	-	100	-	100	100	-	-	-	100	-
Airplane	-	-	-	-	-	-	-	-	-	-

Table 4. Frequency of transport facilities (number)

Type of transport facility	Direction of delivery of goods for the construction (R – Route)									
	R <sub>1</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	R <sub>7</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>	
Car & pick up	-	-	-	-	-	-	-	-	-	-
Van	-	-	-	-	-	-	-	-	-	-
Van up to 3,5t	3	16	-	10	-	406	296	-	-	-
Van over 3,5 – 7t	7	19	-	34	-	676	445	-	-	-
Van over 7t	90	98	-	92	-	2452	1815	-	-	-
Wagon	-	-	-	-	-	-	-	131	-	-
Ship	-	-	9	-	11	4	-	-	-	15
Airplane	-	-	-	-	-	-	-	-	-	-
<b>TOTAL</b>	<b>133</b>	<b>9</b>	<b>136</b>	<b>11</b>	<b>4</b>	<b>3534</b>	<b>2556</b>	<b>131</b>	<b>15</b>	

It is clear that the construction industry uses sea water gates and dominant transport system, which can be interpreted as a positive influence not logistics opportunities in the region.

**3.3. Logistics flows for trade - G3**

Retail trade in the region generated 232,087t of goods. Grocery stores participate with 81.70%, stores with technical goods participate with 6.37%, stores with consumer goods participate with 1.25%, with footwear and textiles with 0.57%, and stores with other goods with 10.11%.

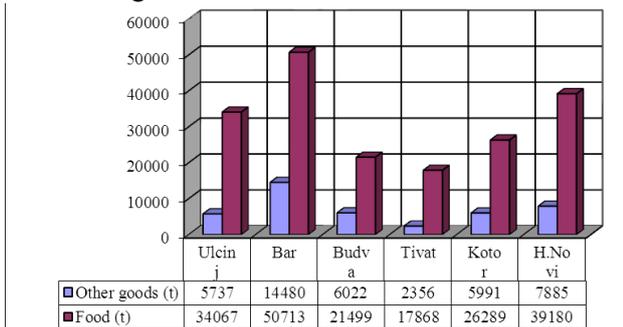


Figure 10. Flows for trade per city of the region [2]

69.4% of goods flows (as in Figure 19) were realized by land, 30.5% by water, and 0.1% by air way.

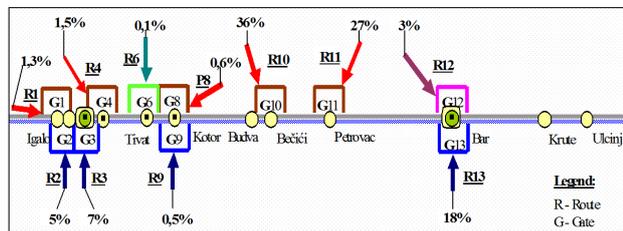


Figure 11. G3 - Goods flows [2]

Table 5. G3 - Transport facilities (%)

Type of transport facilities	Direction of delivery of goods for the trade (R – Route)												
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>6</sub>	R <sub>8</sub>	R <sub>9</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>		
Car & pick up	-	-	-	1	-	3	-	3	2	-	-		
Van	2	-	-	11	-	20	-	13	14	-	-		
Van up to 3,5t	3	-	-	24	-	45	-	18	19	-	-		
Van over 3,5–7t	30	-	-	32	-	30	-	34	35	-	-		
Van over 7t	65	-	-	32	-	2	-	32	30	-	-		
Wagon	-	-	-	-	-	-	-	-	-	100	-		
Ship	-	100	100	-	-	-	-	-	-	-	100		
Airplane	-	-	-	-	100	-	-	-	-	-	-		

Table 6. G3 - Frequency of transport facilities (number)

Type of transport facilities	Direction of delivery of goods for the trade (R – Route)												
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>6</sub>	R <sub>8</sub>	R <sub>9</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>		
Car & pick up	-	-	-	69	-	89	-	5113	2606	-	-		
Van	40	-	-	213	-	186	-	7241	5849	-	-		
Van up to 3,5t	37	-	-	334	-	251	-	6016	4762	-	-		
Van over 3,5–7t	181	-	-	223	-	84	-	5681	4386	-	-		
Van over 7t	129	-	-	66	-	3	-	1783	1253	-	-		
Wagon	-	-	-	-	-	-	-	-	-	697	-		
Ship	-	4	6	-	-	2	-	-	-	-	13		
Airplane	-	-	-	-	335	-	-	-	-	-	-		
<b>TOTAL</b>	<b>387</b>	<b>4</b>	<b>6905</b>	<b>335</b>	<b>613</b>	<b>2</b>	<b>25834</b>	<b>18856</b>	<b>697</b>	<b>13</b>			

**3.4 Logistics flows for hotels and catering – G4**

Generators regarding the hotels and catering were generated 76,643t of goods (as in Figure 20).

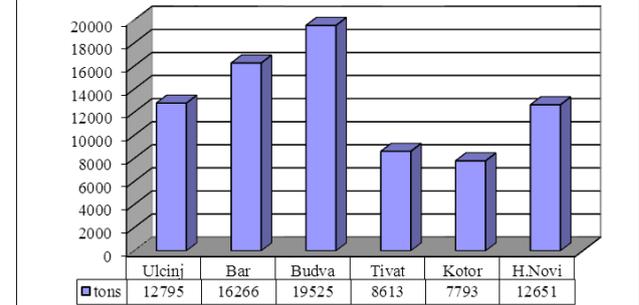


Figure 12. Volume of trade in goods per city – G4 [2]

78.95% of goods flows (as in Figure 13) were realized by land ways, 21% by water ways, and 0.05% by air ways. K10 and K11 gates are the busiest when it comes to hotels and restaurants. With all previous load can be concluded that in these directions has the largest road network congestion and to the right to look for a good solution.

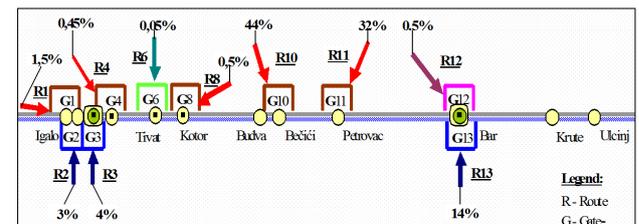


Figure 13. G4 - Goods flows [2]

Table 7. G4 - transport facilities (%)

Type of transport facilities	Direction of delivery of goods for the hotels and catering (R – Route)												
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>6</sub>	R <sub>8</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>			
Car & pick up	-	-	-	2	-	3	3	2	-	-			
Van	2	-	-	16	-	29	14	15	-	-			
Van up to 3.5t	4	-	-	24	-	38	17	18	-	-			
Van over 3.5 – 7t	32	-	-	31	-	28	37	35	-	-			
Van over 7t	62	-	-	27	-	2	29	30	-	-			
Wagon	-	-	-	-	-	-	-	-	100	-			
Ship	-	100	100	-	-	-	-	-	-	100			
Airplane	-	-	-	-	-	100	-	-	-	-			

Table 8. Frequency of transport facilities (number)

Type of transport facilities	Direction of delivery of goods for the hotels and catering (R – Route)												
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>6</sub>	R <sub>8</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>			
Car & pick up	-	-	-	23	-	38	3360	1633	-	-			
Van	15	-	-	37	-	74	3144	2450	-	-			
Van up to 3.5t	18	-	-	34	-	58	2291	1764	-	-			
Van over 3.5 – 7t	74	-	-	19	-	21	2493	1715	-	-			
Van over 7t	59	-	-	8	-	1	814	612	-	-			
Wagon	-	-	-	-	-	-	-	-	39	-			
Ship	-	2	3	-	-	-	-	-	-	5			
Airplane	-	-	-	-	132	-	-	-	-	-			
<b>TOTAL</b>	<b>166</b>	<b>2</b>	<b>3</b>	<b>121</b>	<b>132</b>	<b>192</b>	<b>12102</b>	<b>8174</b>	<b>39</b>	<b>5</b>			

**3.5 Logistics flows for other generators – G5**

Group of other generators were generated 63,757t of goods.

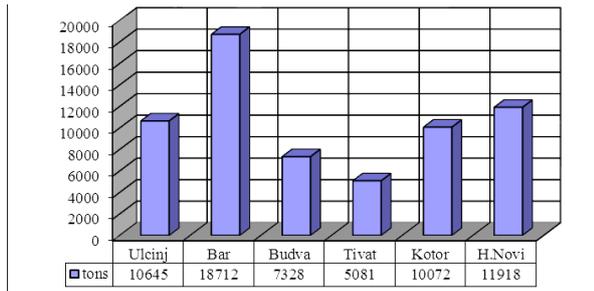


Figure 14. Volume of trade in goods per city – G5

Regarding the directions, 4.81% of goods flows (as in Figure 15) were implemented by land routes, 74.13% by water routes, and 1.05% by air.

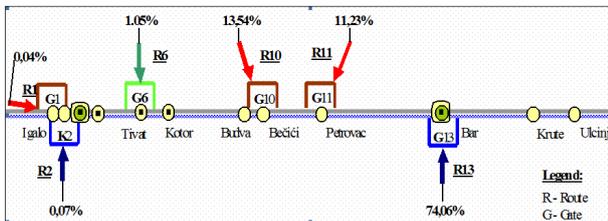


Figure 15. G - Goods flows [2]

Dominantly loaded gate K13, which is convenient because it uses the waterway.

Table 9. G5 - transport facilities (%)

Type of transport facilities	Direction of delivery of goods for the other gen (R – Route)										
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>6</sub>	R <sub>8</sub>	R <sub>10</sub>	R <sub>11</sub>	R <sub>12</sub>	R <sub>13</sub>	
Car & pick up	-	-	-	2	2	-	-	-	-	2	
Van	4	-	-	20	20	-	4	-	-	20	
Van up to 3,5t	5	-	-	20	18	-	5	-	-	20	
Van over 3,5 – 7t	41	-	-	38	35	-	41	-	-	38	
Van over 7t	50	-	-	20	25	-	50	-	-	20	
Wagon	-	-	-	-	-	-	-	-	-	-	
Ship	-	100	-	-	-	100	-	100	-	-	
Airplane	-	-	100	-	-	-	-	-	100	-	

Table 10. Frequency of transport facilities (number)

Type of transport facilities	Direction of delivery of goods for other gen. (R – Route)						
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>6</sub>	R <sub>10</sub>	R <sub>11</sub>
Car & pick up	-	-	-	48	41	-	-
Van	5	-	-	965	816	-	5
Van up to 3,5t	3	-	-	579	440	-	3
Van over 3,5 – 7t	14	-	-	550	428	-	14
Van over 7t	7	-	-	125	135	-	7
Wagon	-	-	-	-	-	-	-
Ship	-	1	-	-	-	4	-
Airplane	-	-	14	-	-	-	-
<b>TOTAL</b>	<b>29</b>	<b>1</b>	<b>14</b>	<b>2267</b>	<b>1860</b>	<b>4</b>	<b>29</b>

#### 4. DIRECTIONS FOR FURTHER RESEARCH

The performed studies provide the basis for further research, which can be directed in three directions:

1. *Research on the developed simulation model:* (i) the analysis of the optimal size of the LC in the region, (ii) economic and environmental

effects of changing the structure of the transport means in transporting and distributing goods, (iii) analysis of optimal cooperative relations between regional logistics operators.

2. *Research on the annex simulation model for the introduction of new distribution technologies:* (i) exploring possibilities of introducing new technologies of distribution based on a combination of fast boats and cross docking terminal, which would be associated with fuel cell vehicles for further distribution of goods, (ii) economic analysis and environmental effects of new technologies of distribution;
3. *Research that can be done using modern methods of operations research:* genetic algorithms, bee colonies, Hub location problems, etc.

#### 5. CONCLUSION

All-embracing definition of the characteristics of the existing logistic system within the MCR as well as empirical data gained through research make solid foundation for development of a simulation model and further research on him in order to develop a new concept of logistics in this region.

The importance of the article is that it showed the practical application of a methodology for the analysis of regional logistics.

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# DEVELOPMENT PERSPECTIVES OF THE LOGISTIC INDUSTRY IN CROATIA UPON ACCESSION TO THE EUROPEAN UNION

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**Abstract:** *Accession to the European Union significantly decreases incomes based on customs brokerage, but yields new development perspectives for Croatian logistic industry, primary in the field of physical distribution and transit traffic. By integration into the single European market, the logistics infrastructure in Croatia is gaining importance, and the market positions previously acquired by global logistics operators will be strengthened up, which will result in further attracting of cargo flows. Hence, the need for further development of the Corridor Vb occurs, as well as setting up a modern logistics distribution center in continental Croatia, who could also act as a background terminal of the Port of Rijeka.*

**Keywords:** *development, logistic industry, Corridor Vb, background terminal.*

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## 1. INTRODUCTION

Croatia has become the twenty-eighth member of the European Union, which introduced changes for Croatian logistics industry and opened new opportunities for the development of logistics activities. Changes in the part of the customs operations relating to NCTS (New Computerised Transit System), Intrastat, HRAIS with different tariff procedures made logistic operators to reorganize and define new business strategies. Users of logistics services expect faster, safer and less expensive transport due to elimination of customs procedures at border crossings and in trade within the EU zone.

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 the intermodal transport of goods, which is a standard in developed economies; efficient, economical and environmentally oriented. In addition to international transport, logistics operators should develop respective value-added services for transit goods coming from third countries to the European market and going from the EU to third countries. Also, there are opportunities to organize cross-

docking centers due to the relocation of international company in Slovenia on Croatian territory according to the regional redeployment of business operations.

A common theory about the arrival of "foreign players" to the market of Croatian logistics services have no right signification, since global logistics operators have been present in Croatia for many years and have acquired positions in the market. Above mentioned development of adequate cross-docking centres assumes transport optimizing at shipping and delivery, in order to meet the constant demands for reducing transport costs.

With respect to the fact that over the last five to seven years a significant amount of logistics infrastructure capacity has been built in Hungary, the need for further development of Vb Rijeka corridors becomes more evident, as well as development of other related activities of the logistics industry.

## 2. IMPACT OF INTEGRATION INTO THE SINGLE EUROPEAN MARKET TO THE CROATIAN LOGISTIC INDUSTRY

It is too early for a serious analysis of the effects to the Croatian logistic industry, as Croatia has joined the EU less than two months ago. Therefore, as no relevant statistical data has been available yet,

some preliminary assessments could be based on available data in the period from July to the first part of August and on similar experience from Slovenia, which corresponds with the prospective situation in Croatia.

Main aspects of European integration affecting the logistic industry in Slovenia could be summarized as follows:

- Customs borders with neighbouring EU countries have been eliminated, while Slovenian border against Croatia has become a part of the customs border of the EU;
- Port of Kopar has become EU port, i.e. an entry point to the European market;
- Slovenia has become a convenient transshipment station for European distribution networks in supplying markets of former Yugoslavian countries.

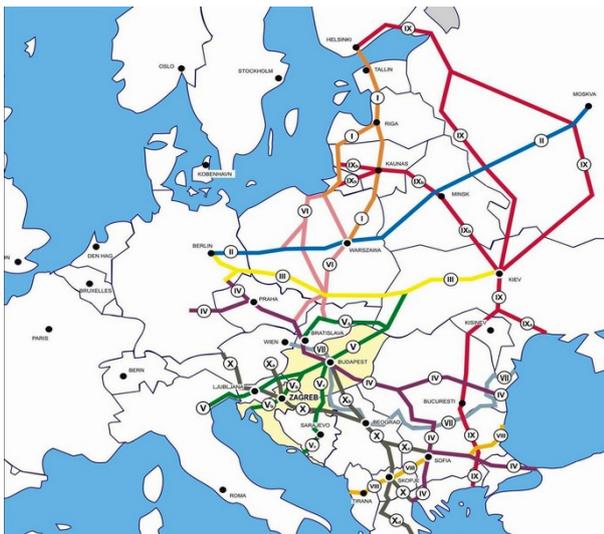


Figure 1. Pan – European Transport Corridors [7]

These aspects, that affected the logistic industry in Slovenia, could easily be translated into the situation in Croatia, with some exceptions such as:

- Croatian market is almost twice the market in Slovenia;
- 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, as shown on the Figure 1;
- The shape of the Croatian national territory is much more complex to be covered in terms of distribution.

As there was no relevant statistical data available, authors have made an informal short term inquiry

among relevant logistic operators (freight forwarders) and at the two major cargo (customs) terminals in Croatia. The information gathered refers to the traffic in July and in the first two weeks of August. For this purpose, it has been considered representative enough. Primary impacts to the Croatian logistic industry could be summarized as follows:

### 2.1 Customs operations

Number of customs operations in July hasn't been significantly decreased due to the transport & customs procedures started before 1st of July which therefore needed to be closed according to the old regulations. It caused traffic jam at the borders and at the customs terminals, as most of the freight forwarders had already cut down the staff or had closed some or all of their offices. Also the customs software needed some time to adopt. The situation has normalized by the end of July. Significant decrease of the number of customs declarations has been registered at the end of July and continued in August. It is expected at least 60% less customs declaration than in August 2012.

### 2.2 Warehouse & local delivery/collection operations

For similar reasons as with the administrative customs operations, customs warehouses have remained busy in the first part of July, but with negative tendency in August. Operations in non bonded warehouses and local delivery/collection operations have remained at the same level. Exception is increase of logistic operations related to e-commerce (online shopping) and courier service.

### 2.3 International transport

There hasn't been any significant impact to the volumes of international cargo transport within the aforementioned period. However, freight rates in road transport, which is the dominant mode of transport in Croatia (Cf. Figure 2.) have been decreased. There has been some increase in the number of shipments in courier and parcel express service.

### 2.4 Intrastat reporting

Intrastat reporting was expected to partly compensate the loss of incomes generated out of customs brokerage, but such expectations appeared to be groundless. Many companies haven't been included in the Intrastat system due to relatively high threshold value (1,7 million kn total value of trade with EU countries per year), while the service

fees for Intrastat reporting were much lower than fees for customs brokerage.

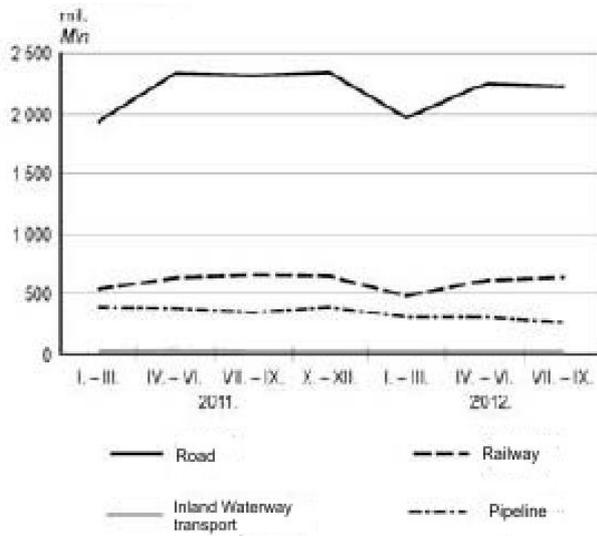


Figure 2. Tkm performed in inland transport [1]

### 3. DEVELOPMENT PERSPECTIVES FOR CROATIAN LOGISTIC INDUSTRY

The most visible negative impact of accession to the EU refers to decrease of incomes based on customs brokerage. It is expected more than 2.000 employees at freight forwarding companies to lose their jobs for that reason. Next thing is decrease of the road freight rates which has been welcomed by the clients, but puts additional burden to the carriers and logistic operators.

However, accession to the EU yields new development perspectives for Croatian logistic industry, as explained hereinafter.

#### 3.1 Distribution

Croatia has become a part of the single EU market and a prospective transshipment station for European distribution networks in supplying markets of former Yugoslavian countries, so it is expected a significant part of logistic operations in international distribution to be shifted from Slovenia to the terminals in Croatia.

#### 3.2 E-commerce, courier/parcel express service

Growth of online shopping generates demand for adequate logistic services, provided by operators specialized in courier/parcel express service. Most of the European e-commerce companies (internet based retailers) offer delivery only within the EU market, so upon accession, logistic operators in Croatia can gain a new traffic.

Volume of courier express shipments is also expected to increase due to simplified customs

procedures with export/import shipments and no customs formalities with European shipments, which also enables logistic operators to cut down the costs.

#### 3.3 Transit traffic & customs operations

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 logistics 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, as well as setting up a modern logistics distribution center in continental Croatia, who could also act as a background terminal of the Port of Rijeka, as further explained in the following paragraph.

Since Croatia holds the part of EU border on its territory, customs operations in transit (NCTS) over Croatia are to be done at Croatian part of EU border. Also the import/export customs clearance for EU countries can be done in Croatia.

### 4. DEVELOPMENT OF LOGISTICS ACTIVITIES RELATED TO VB CORRIDOR

Department of Transport Logistics at the Faculty of Transport and Traffic Sciences, University of Zagreb, conducted research focused on the analysis of the construction of modern logistics and distribution center (LDC) in continental Croatian (so-called the Zagreb ring) that would replace the already inadequate container terminal at Zagreb Vrapče and represent background terminal of the port of Rijeka. Trade flows over such LDC are related to the Pan-European Corridor V, and its branch Vb (Botovo-Rijeka). Prospectively, the commodity flows within the gravity zone of that LDC would be bound also for the Route 65. Development of Routes 65 aims to establish a green transport corridor from the Swedish region of Skane across Polish, Czech, Slovakia, and Hungary to the Croatian port of Rijeka, as the shortest route to connect the Baltic and Adriatic, and thus contribute to better traffic connections and economic development and standard of living within the corridor region.

The port of Rijeka handled 72.559 TEUs in the first six months of this year, which is about 12% more than the same period last year. Total turnover of the port of Rijeka (Luka Rijeka d.d. and Adriatic Gate Container Terminal – AGCT) was 4.511 million tons of cargo in the 2012. Traffic of goods in Luka Rijeka d.d. in the segment of general cargo,

bulk and timber amounted to 3.235 million tonnes and it was at the same level as in 2011. General cargo traffic increased by 2%, timber traffic by 39%, while the volume of bulk cargo decreased 6%. Traffic of AGCT was 128,680 TEUs in the 2012., decreased by 3% compared to the year 2011. [6]

Planned total turnover of dry cargo in the 2013. is 5,032 million tons. Luka Rijeka d.d. in 2013 has planned to realize turnover of general bulk cargo and timber of 3,450 million tons, and that is increase of 6.7%, and AGCT container traffic of 157,000 TEUs, an increase of 24%. According the plan, an increase in the total turnover of dry cargo in the 2013 year should amount 11.5%. Optimistic fact is that traffic in June was a record month at the terminal with 17,748 TEUs, which should be only a prelude to further growth by the end of the year. These results were provided by series of investments in the terminal, primarily in the construction of new 328 meters of port terminal and the arrival of new equipment worth a total of about 23 million. Because of Croatian accession to the European Union and implementation of new conditions, constant coordination of the Adriatic Gate Container Terminal (AGCT) with partners (shipping companies, customs, agents and logistics operators) is needed and procedural changes corresponding with the new customs regulations implemented upon entering the EU. [6] Previous research of the Faculty of Transport and Traffic Sciences have shown that traffic at the container terminal Vrapče in Zagreb is approximately 10% of the container traffic in the port of Rijeka. Therefore, it will proportionally grow with the increase of container traffic in the port of Rijeka, which indicates the need for a new LDC, as the background terminal of the port of Rijeka.

Forecasts and analysis indicate that container traffic via the port of Rijeka is expected to increase significantly in the period of the next ten years. According to the actual circumstances (change of the container terminal owner) these forecasts can be considered relevant. Prospective new LDC could be a point of processing and preparation of containers directed towards the port of Rijeka. This assesment is based on the fact that approx. 90% of traffic at the container terminal Vrapče originates from the port of Rijeka. This strategic objective also complies with the concept introduced by the new container terminal operator in Brajdica. [5]

Intermodal transport sector (excluding container traffic) on Croatian territory has been neglected, while the road transport has been dominant, primary for goods originating from European countries and distribution centers in those countries. [5] Due to

expected increase in the volume of transit goods and in the number of containers transhipped at the port of Rijeka, there is a need for additional parking areas for trucks, which would be one of the facilities within the prospective new LDC. That LDC would provide additional development opportunities for logistics operators in urban logistics, underdeveloped logistics activities in Croatia. It would enable development of new logistics solutions for improving distribution of goods to end-users and to generate revenues for logistic operators.

## 5. CONCLUSION

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 the logistic activities. Growth of online shopping generates demand for adequate logistic services, provided by operators specialized in courier/parcel express service. Most of the European e-commerce companies (internet based retailers) offer delivery only within the EU market, so upon accession, logistic operators in Croatia can gain a new traffic.

By integration into the single EU market, the Port of Rijeka becomes an EU port and the logistics infrastructure in Croatia is gaining importance. Forecasts and analysis indicate that container traffic via the port of Rijeka is expected to increase significantly in the period of the next ten years. Hence, the need for further development of the Corridor Vb occurs, as well as setting up a modern logistics distribution center in continental Croatia, who could also act as a background terminal of the Port of Rijeka.

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## FINANCIAL RISK MANAGEMENT IN GLOBAL LOGISTICS

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***Abstract:** The paper presents and analyzes changes in global trade, global logistics markets and financial instruments used to value and hedge services in global logistics markets. The logistics industry is an interesting example on how physical markets have followed the state of financial and information markets in such a way as to support globalization and outsourcing. It is also one of the necessary elements of infrastructure that supports the expansion of international trade. The integration of financial and physical markets is a main force for the emergence of global logistics. The growing need of insurance in a changing volatile business environment resulted in the expansion of financial instruments. Risk management products based on derivatives, such as futures, forwards, options and swaps can provide the backbone for risk management in logistics. Derivatives are an important financial instruments because they allow risks to be separated and controlled. Logistics has followed the trend similar to all other commodity markets, from purely physical contracting, to full derivatives markets for valuation, sourcing and hedging.*

***Keywords:** globalization, physical and financial markets, financial risk, derivatives.*

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### 1. INTRODUCTION

The evolution of logistics markets, and their integration with physical and information markets, resulted from the process of globalization and expansion of international trade. The network effects of globalization, unbundling and re-bundling encompassed by the new logistics are staggering. The supply chains have become long and complex global networks within which a multitude of actors are highly interconnected through goods/services, information, and financial flows.

The economic history of globalization shows how specialization and trade stimulate economic growth and why integration of financial and physical markets is necessary to mediate value-added networks.

The new global business environment created by globalization creates new challenges and risks for every participant in international trade and global logistics. These new risks and above all financial risks are the subject of this paper. The appearance and use of new financial instruments (financial derivatives) on financial markets provide the opportunity to companies to manage and hedge these types of risks.

### 2. GLOBALIZATION, WORLD TRADE AND GLOBAL LOGISTICS

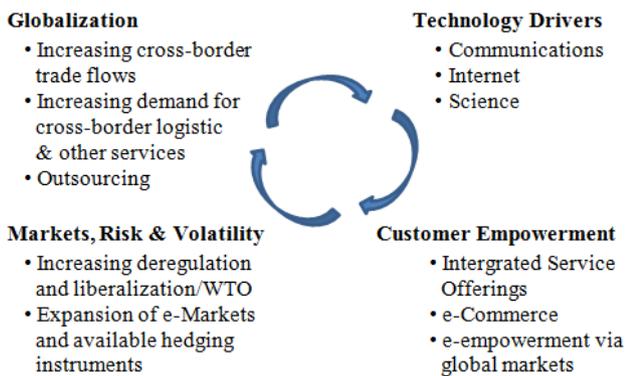
The last decades have seen vast changes in the functioning of the world economy, dubbed as globalization. According to the World Bank, globalization refers to the growing interdependence of countries resulting from the increasing integration of trade, finance, people, and ideas in one global marketplace. International trade and cross-border investment flows are the main elements of this integration. Globalization started after World War II but has accelerated considerably since the mid-1980s. It was driven by two main factors. One involves technological advances that have lowered the costs of transportation, communication, and computation so that it is often economically feasible for a firm to locate different phases of production in different countries. The other important factor refers to the liberalization of trade and capital markets [13].

Empirical evidence suggests that globalization has significantly boosted economic growth in East Asian economies such as Hong Kong (China), the Republic of Korea, and Singapore. But not all developing countries are equally engaged in globalization or in a position to benefit from it. The

most developing countries have been rather slow to integrate with the world economy [12]. Moreover, for countries that are actively engaged in globalization, the benefits come with new risks and challenges. The globalization's costs and benefits for different groups of countries and the world economy is one of the most challenging topics in development debates.

The volume of world trade increased twenty-seven fold from \$296 billion in 1950 to \$8 trillion in 2005 [14]. In recent years world trade has declined in volume and was down in 2012 and is expected to remain sluggish through 2013. This is a result of the struggling economies of Europe and crises of Eurozone. As a result, world trade growth fell to 2.0 per cent in 2012 — down from 5.2 per cent in 2011 — and is expected to climb only slightly in 2013, to around 3.3 per cent [15].

Logistics become one of the key factors in the global interdependence that determines profitability and uncertainty for management, Figure 1.



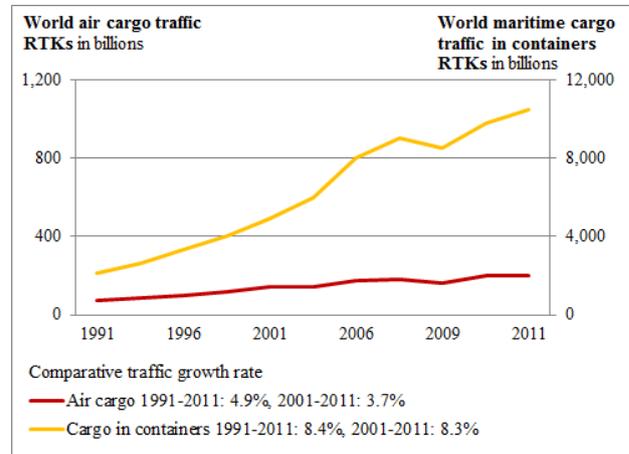
**Figure 1. Key factors of interdependent mega trends [8, p.6]**

In international trade, containership cargo traffic is estimated at 10.5 trillion revenue tonne-kilometres (RTKs) in 2011, while world air cargo traffic is 202 billion (RTKs). The largest containership markets mirror the largest air cargo markets. In 2011, Europe–Asia was the largest containership market, with 2.8 trillion (RTKs), followed by Asia–North America with 1.9 trillion RTKs and Europe–North America with 0.3 trillion RTKs [3].

Until the global economic recession of 2009, the containership industry had grown steadily every year since its inception. Between 1980 and 2011, containership tonnage averaged 8.9% growth per year.

Expansion of physical capabilities in international logistics began in the 1990s and has continued with increases in capacity in nearly every established port and air hub. This increase in physical capabilities was accompanied by increased sophistication and intermediation activities of

brokers and forwarders, followed by the development of financial overlays and trading instruments for air cargo and shipping capacity. In the last decades, globalization and the associated unbundling of value chains have been the most influential in the growth of logistics[8].



**Figure 2. World containership traffic growth and air cargo growth [3, p.8]**

A number of different organizations and economics transactions are involved in the basic structure of international logistics operations as shown in Figure 3. Some of these are public (e.g. terminal and port facilities) and some are private. Tremendous growth of global trade gave rise to increasingly liquid markets for buying and selling services. These markets used to be contract markets for physical capacity. But, during the last decade the financial instruments took on a very important role in international air cargo and maritime operations with the main goal of facilitating price discovery and risk management.

In international logistic market sellers of logistics services compete to supply buyers of such services. Buyers can reserve capacity through forward contracting or through various types of options obtained from the seller. Sellers compete for the buyer's business in the forward and contract market. In the short term market (the spot market), competitive spot market price is determined. In the contract market, larger buyers and sellers often have long-term relationships because they need to satisfy credit requirements, insurance and other criteria. But, even in that case, buyers still use spot markets as a second source of supply for some of their logistics services and as a means of evaluating prices in contract purchases.

In so complex environment it is of great importance to have market-traded instruments that provide transparent and objective information on availability of various logistics services as well as their prices.

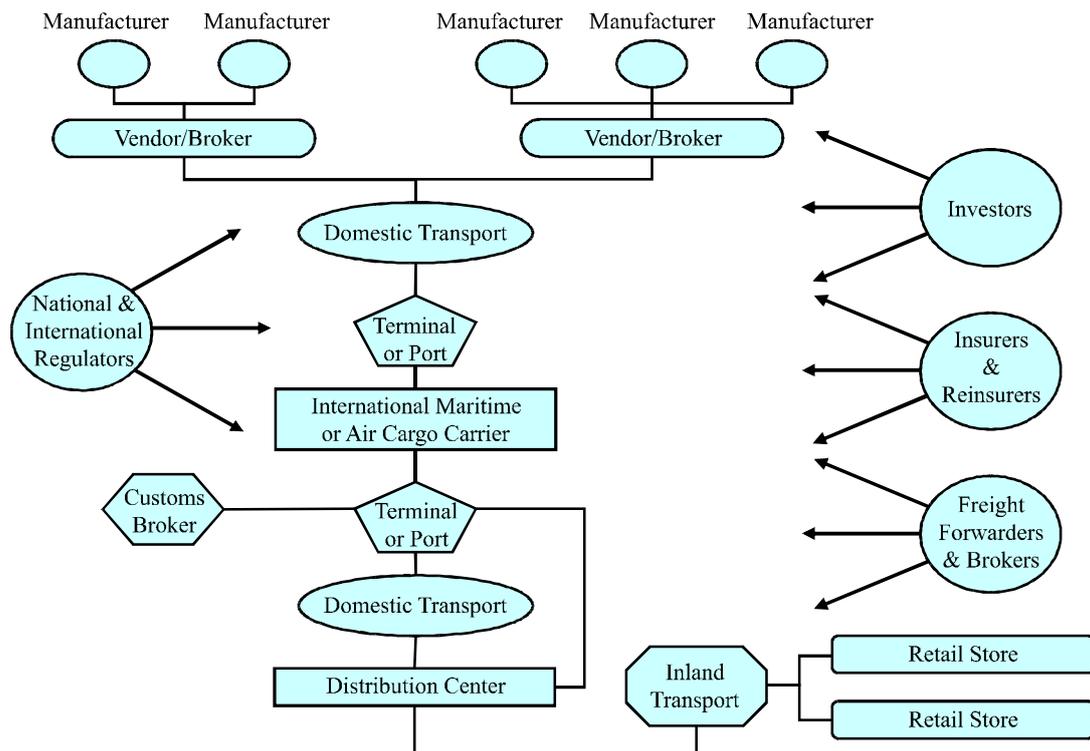


Figure 3. Actors in Global Supply Chains [8, p. 11]

### 3. FINANCIAL RISK MANAGEMENT IN SHIPPING

We intuitively associate risk with a probability of an undesired outcome. In economics, risk refers to situations in which we can list all possible outcomes and we know the likelihood that each outcome occurs [10]. In finance, risk is a possibility that the actual outcome is likely to deviate from the expected value. Risk is equated with uncertainty in payoffs, which will be referred to as profit variability risk. Risk then implies the existence of some random variable whose standard deviation or variance can be used as a measure of risk.

Operational risks are risks that resulted from operations, i.e. from activities and resources. Any potential source that generates a negative impact on the flow of information, goods, and cash in our operations is an operational risk. The inclusion of cash implies that financial and operational risks are not mutually exclusive [9].

Fundamentally, the value of a company depends on the expected net cash flows from its operations. Therefore, any factor that may have a negative impact on the expected net cash flows is identified as a risk. Harrington and Niehaus classify business risks in three categories: price risk, credit risk and pure risk [5].

Price risk refers to uncertainty over the magnitude of cash flows, due to possible changes in

output and input prices. A vast literature deals with risks of shipping companies, i.e. freight-rate risk. This risk refers to the variability in the earnings of a shipping company due to changes in freight rates. Volatility in freight markets has a direct impact on the profitability of the company.

Volatility on the costs side is also a factor affecting the profitability of shipping companies. Perhaps the most important cost components for a shipping company is the cost of fuel oil, called bunkers, used by the vessel in performing a voyage. Bunker costs, on average, account for more than 50 per cent of the total voyage costs [1].

Interest-rate risk arises from exposure to changes in interest rates. The capital-intensive nature of air and shipping companies implies that most vessel acquisitions are financed through term loans priced on a floating rate basis. Unanticipated changes in interest rates may create cash flow and liquidity problems for companies which may no longer be able to service their debt obligations.

Credit risk, also known as “counter-party risk”, is the uncertainty surrounding whether a counter-party to a transaction will perform its financial obligations in full and on time.

Pure risk is defined as the risk of reduction in the value of business assets due to physical damage, accidents and losses.

The risk-management process includes: (i) risk identification; (ii) risk evaluation; (iii) risk management; and (iv) risk monitoring.

The first step in the risk-management process is risk identification (identification of loss exposures). Risk identification requires an overall understanding of the business and the specific economic, legal and regulatory factors which affect the business.

Risk evaluation involves managers quantifying the exposure of the company to each risk factor, and usually involves measuring the expected losses and the standard deviation of losses over a period of time. This step generates the right incentive for a company to hedge. Another important parameter here is the sensitivity of each company to the different risk factors. For instance, an increase in bunker prices will, in general, have a negative impact on the cash flow positions of shipping companies. However, this impact will be less for a company that has chartered out her fleet on a long term basis, compared to a company that operates in the spot market and will therefore need to increase freight rates in order to maintain its profit [10].

The next step is the selection of the instruments which are best suited to the management of those risks. This depends on the type of risk that is to be hedged. Price risks are managed using derivative contracts such as futures, options and swaps.

The last step in the risk-management process is monitoring the performance and suitability of the risk-management methods and strategies on an ongoing basis.

One of the most important steps in any risk-management process is risk measurement and quantification. In shipping, fluctuations of freight rates, bunker prices, ship prices, and even interest rates and exchange rates can have a severe impact on the operating profitability and business viability of the agents involved [4].

During the last decade, the growth of financial instruments has been driven by underlying demand for risk management products.

#### 4. FINANCIAL DERIVATIVES AND THEIR USE IN SHIPPING

Financial derivatives are financial instruments that are linked to a specific financial instrument or indicator or commodity, and through which specific financial risks (such as interest rate risk, foreign exchange risk, equity and commodity price risks, credit risk etc.) can, in their own right, be traded in financial markets [6].

Financial derivatives are used for a number of purposes including risk management, hedging,

arbitrage between markets, and speculation. Before derivatives products were originally designed to meet the needs of hedgers. Organised trading in commodity futures markets dates back to the mid-1860s with the opening of the Chicago Board of Trade. The market at the time was designed to assist farmers who wanted to lock in advance a fixed price for their harvest.

If we take value of underlying entities such as an asset, index or interest rate, we can derive the value of financial instruments called derivatives. It has no value in itself. Derivative contracts could be based on structured debt obligations and deposits, swaps, options, futures, forwards and some other variety of financial contracts. Derivatives can be traded in OTC (over-the-counter or off-exchange trading) and on organized markets. For shipping charterers the most important derivatives are: forward, futures and swap. Each of these types of contracts bind the parties to exchange money or goods according to a predetermined schedule in the future. Swap contracts are more complex, but can be easily decomposed to the portfolios of forward contracts.

Financial transactions commonly take place on the spot market. This implies that delivery of goods or securities must take place as soon as possible. In contrast to these spot contracts are term contracts. The first form of term contract was a forward contract or simply forward. That is a non-standardized agreement between two parties, about exchange of a certain asset for cash, at a specified future time at a price agreed upon today. One party is buying the underlying asset in the future and takes the so called, long position, while the other party is agrees to sell that asset and assumes a short position.

Delivery price is the price both sides agreed upon, and actually that is the price of the forward contract at the time of the agreement. All exchanges are made solely on the due date, that is a forward contract has no cost. However, at maturity one party will be at a loss compared to the other [11]. Obviously, the profit of the long position is the same as the loss of the short position, which means that the contract is a zero-sum game.

Understanding the basis is fundamental to using futures for hedging. The basis in a hedging situation is defined as: spot price of the asset to be hedged,  $S_t$ , minus the price of forward contract used for hedging,  $F(t, T)$ :

$$\text{Basis} = S_t - F(t, T) \quad (1)$$

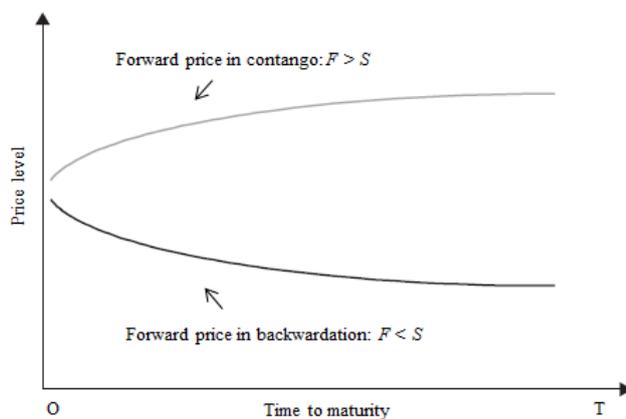
Depending on the sign of the basis, the market is also characterised as being in 'backwardation' or 'contango'. For instance, if the basis is positive (that is, the spot is higher than the forward) we say that

this contract is backwardated. On the other hand, if the basis is negative then the market is in contango.

The terms backwardation and contango are also used to describe the entire shape of the forward curve as well. For instance a rising forward curve, where forward prices increase as time to maturity increases, is said to be in contango; and a falling forward curve is said to be in backwardation, as shown in Figure 4. [1].

Since forward contracts are just agreements on the exchange in the future, they certainly carry credit risk. Futures contracts are precisely specified to be a way to reduce this credit risk to a minimum. In its essence futures contracts do not differ too much from the forward contracts. Both contracts represent the two parties' agreement on the exchange of two assets in the future at a predetermined price.

Again parties taking two different positions; the buyer (the party agreeing to buy the underlying asset) assumes a long position because of expectations that the asset price is going to increase. On the other hand, the party agreeing to sell the asset in the future, expects that the asset price will decrease in the near future, is said to be "short".



**Figure 4. Backwardation and contango forward curves**

Swaps are derivatives which were first used in 1981 when IBM and the World Bank entered into this type of agreement. With a swap the two sides are agreeing upon the exchange of cash flows. This includes counterparties financial instruments so the cash flows of one party could be exchanged for those of the other party. Therefore, swap contracts are OTC agreements on the exchange of cash flows. Cash flows to be exchanged can be determined by interest rates, currency exchange rates, stock prices or raw materials prices, as well as stock market indexes. Further conditions and treatments depend on the type of financial instruments involved. How much swaps are significant derivatives is shown by the fact that the total amount of interest rates and

currency swaps outstanding is about \$402 trillion in December 2011, according to the Bank for International Settlements (BIS)[2].

An option is a financial instrument which gives its owner the right to buy (in case of Call option) or sell (in case of Put option) an underlying asset at fixed price called an Exercise or Strike price and in some future moment called Exercise time. It gives the right, but does not imply an obligation. Exercise means the exploitation of owner's right given by an option. This Exercise time is limited by time to maturity. After the expiry of maturity, an option ceases to be valid.

There are two types of options according to method of exercise: American and European options. While an European option may be exercised only at the expiration date of the option, an American option can be exercised at any time before the expiration date.

Shipping represents the major mode of transportation of international trade as well as the focal point for value-added logistics services in the world economy. Shipping markets are characterized as capital intensive, cyclical, volatile, seasonal and exposed to the international business environment. That's why the introduction of proper risk management strategies in an industry which is characterized with cycles and high volatility in its prices is important. The existence of derivative products in shipping has made risk management cheaper, more flexible and available to parties exposed to adverse movements in freight rates, bunker (fuel oil) prices, vessel prices, exchange rates, interest rates and other variables affecting the cash-flow position of the shipping company and its customers [7]. Similar trends are emerging for air cargo logistics which are still less developed in the use of these financial derivatives.

## 5. CONCLUSION

The latest experiences on the global logistics services market show that for now and above all, shipping companies have begun to use various financial instruments in order to upgrade and more successfully manage financial risks. Certainly this new area of risk management requires new knowledge and competencies.

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## FINANCING CITY LOGISTICS SOLUTIONS WITH FOCUS ON BELGRADE

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**Abstract:** *The paper analyzes the issues of financing City Logistics solutions pointing out the complexity of evaluation models due to the presence of multiple objectives and multiple stakeholders. Evaluation models of City Logistics require the application of cost benefit analysis and multidisciplinary approaches. The proposed City Logistics solutions for Beograd are given special attention, especially regarding their choices and methods of finance.*

**Keywords:** *City Logistics, economic and financial evaluation, main issues in financing City Logistics, financing City Logistics solutions for Belgrade.*

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### 1. INTRODUCTION

Transport and socio-economic development are closely related and mutually interdependent since the Industrial revolution in the 19<sup>th</sup> century up to the time of the current globalization of trade, supply chains and economic integration on a world scale. Transport systems enable and accelerate economic processes, however producing negative external effects such as congestion, accidents and mobility gaps. Finding optimal solutions from the point of view of further economic and social development and transport systems is one of the priorities of national and regional economic and transport policies of the last decades. These efforts have contributed to the formation of the strategy of sustainable development.

City Logistics have the goal of achieving the overall optimization of freight transportation. This means that it tends to attain an optimum from the socio-economic, transport, land use, customer satisfaction and environmental aspects or, in short, sustainable urban development. This is not an easy goal at all. This needs a multidisciplinary scientific approach in creating models of City Logistics.

In this paper we wish to point out the phases through which city logistics projects should pass in order to enable competent methods of choosing and deciding on projects from the aspect of their financing. The presence of multiple stakeholders is obvious. Multiple goals and multiple stakeholders in City Logistics as compared to other transport

infrastructure projects results in a complex evaluation process and a complicated procedure of adopting policies.

There are three important components relating to freight transport: (i) economic growth, (ii) demand for freight transport and (iii) impacts on congestion and environment [1]. Transportation of goods represents a vital factor of the economic and social being of the city both from the point of view of the citizen as users and the firms established within the city zone. Freight transportation is also a major distributing factor for urban life [2].

The support of freight as an urban activity relies on distribution strategies, including modal choice, that insure an adequate level of service, so that providers of City Logistics are able to meet the needs of their customers. The urban freight distribution center can be a neutral facility interfacing with a set of distribution centers, each being connected to their respective supply chains. In this way a wide array of supply chains connected to the city can achieve a better distributional efficiency within the central city. Each city represents a unique setting with its own prevalence of transport infrastructure and modal choice, therefore appears to be no single encompassing strategy to improve urban freight distribution, but a set of strategies reflecting challenges that are rather unique for each city.

## 2. MAIN ISSUES IN FINANCING CITY LOGISTICS

In 1992 Ogden pointed out that City Logistics has the overall objective to reduce the total social cost of urban goods movement. He further divides this overall objective in six specific objectives: (i) economic; (ii) efficiency; (iii) road-safety; (iv) environment; (v) infrastructure & management; and (vi) urban structure [3]. There are two different groups who are capable of changing the urban freight system. One is company-driven change where companies implement measures that will reduce the impact of their freight activities operating in a more environmentally or socially efficient manner. Second, changes implemented by governing bodies, i.e. the introduction of policies and measures that force companies to change their actions and thereby become more environmentally or socially efficient (e.g. changing the way in which they undertake certain activities).

The complexity of the City Logistics domain is also considerably due to its emergence phenomenon which appears when a number of stakeholders operates and forms complex behaviour as a collective.

The number of interactions between components of a system increases combinatorially with the number of stakeholders, thus potentially allowing for many new and subtle types of behaviour to emerge. Multiple actors' perspective refers to analyzing interactions of autonomous stakeholders with a view to assessing their effects on the system as a whole.

City Logistics initiatives are usually operated by private companies with varying degrees of support provided by the public sector. To put into effect the full potential of city logistics initiatives, it is, therefore, crucial that an effective partnership between both the private and public sector be developed and maintained. City Logistics concepts aim at the integration of different perspectives of particular stakeholders. The most important stakeholders are as follows [4]:

- Shippers who send goods to other companies or persons and receive goods from them. They tend to maximize their levels of service in terms of costs and reliability of transport.
- City Logistics service providers who deliver goods to customers. Their objective is the minimization of their costs by more efficient pickup and delivery tours. They are expected to provide a high level of service at low costs.

- Residents who live, work, and shop in the city. They suffer from nuisances resulting from urban freight movements near their residential and retail areas. However, residents also benefit from efficient and reliable delivery.
- City administrators who attempt to enhance city economic development. They are interested in the reduction of congestion and environmental nuisances as well as in increasing safety of road traffic. They observe urban transportation systems as a whole in order to resolve conflicts between the other stakeholders.

City Logistics services providers depend on the interaction of stakeholders presented above. One solution could be for administrators to influence planning procedures by setting complex certain time slots that permit or prohibit the entrance of freight vehicles in pedestrian areas. Residents and shippers react to customers of City Logistics service providers expecting an economic and reliable delivery service.

Considerable numbers of the modeling efforts are carried out from the point of view of an administrator as a sole stakeholder of the City Logistics domain. Most of the literature on urban freight modeling sum up as to how an administrator can create efficient urban freight transportation without considering inputs from other active stakeholders. There are only a few models available in which all stakeholders and their influence in the urban freight domain are included. It would be worthwhile to investigate and incorporate the specifics of using decision methods in urban freight modeling by other stakeholders as well (i.e. shipper, carrier, receiver etc.).

The framework with more generic factors such as the objective, stakeholders' involvement, clusters of their activities and means available for achieving objectives are more determinative for carrying out urban freight modeling. In this way the approach to urban freight policy which Visser has "Learning by doing", that is not effective many times, would be surpassed [5].

Models for providing finance for investment in City Logistics require a social and economic evaluation. In that respect Van Duin at the Fifth International Conference on City Logistics called the need for evaluation using cost benefit analysis (CBA) a "revival of the cost benefit analysis"[6]. CBA is a classical method for the evaluation of investment in transportation infrastructure because these projects have substantial external effects, i.e.

social effects. The Costs of these investments are considerable. The need to include a multistakeholder environment into CBA must be stressed. This is the way to find an optimal solution from the point of view of the stakeholders. As with all large investments a long term period should be used for the evaluation of City Logistics concepts. The evaluation of City Logistics projects using CBA is more complex and demanding as compared to transportation infrastructure investment.

Enhancing development of city logistics concepts contributes to the continuing enrichment of evaluation models. In other words, a financial feasibility study for City Logistics has to convince the investors of the financial efficiency of the project through adequate indicators: cost/benefit ratio, net present value, internal rate of return, recovery time, etc. An economic feasibility study for CL adds to the financial consequences the impact on customers, residents, society, that are not of direct interest to the private investor. Under conditions of uncertainty the preferences of the decision maker should be analyzed for a certain scenarios depending on his/her attitude towards risk [7]. The CBA can be complemented by a "cost efficacy analysis" (CEA) which reflects the manner in which the non-financial, social consequences of the project can be used to rank the decision scenarios. In sum, City Logistics projects require technical evaluation and also financial and economic evaluations. This means that an all encompassing evaluation procedures should be based on overall social costs and benefits.

Generally no major difficulties are encountered when it comes to the ranking of various technical solutions, but in the case of financial and more so the economic assessment of investment projects, controversies continue and stimulate debate between experts of different backgrounds (engineers, economists, sociologists, ecologists, lawyers). Although the two types of analysis (financial and economical) are based on different evaluations, they do have common elements. They both use the classical CBA. Even when the financial flows are determined, the calculation of the net present value (NPV) for a certain project is controversial. The controversies relate to the value of the discount rate (r) used in calculations and the length of the time period (T) over which the financial flows are summed [8].

### 3. FINANCING CITY LOGISTICS SOLUTIONS FOR BELGRADE

The existing problems of City Logistics, world experiences, demands for the alteration of urban

plans primarily in the central city, property rights changes in economic system transitions and alterations in business plans, the vision of the role of Beograd in the logistics of the region, have all contributed to the defining of four concepts of City Logistics [9]:

*CL1*: Decentralized, a satellite system with the dominant role of road transport.

*CL2*: Centralized-decentralized system with the adoption of cargo trolley.

*CL3*: Core network with the adoption of cargo trolley and electrical vehicles.

*CL4*: Network system with intermodal transport.

**Concept CL1** assumes a decentralized system of warehouses for goods on the rim of the city with a certain concentration of logistics systems in planned goods transport center (GTC) in Batajnica and the City Logistics terminal (CLT) in Ada Huja. Given the dominant role of road transport for the logistical needs of the central zone, satellite terminals with adequate infrastructure for cross-docking functions would be developed. The purpose of these terminals is the reloading of goods from larger to smaller delivery vehicles for supplying city zones. The Function of the CLT would be warehousing and distribution of goods by eco-vehicles mostly for the needs of the newly planned complex on the shore of the Danube. Aside of this the CLT would offer reverse logistics services and home delivery. The concept supports the development of small city terminals intended for a certain group of generators such as bars, restaurants and hotels or for certain location such as larger building sites. The aim is consolidated delivery, i.e. a smaller number of vehicles in the function of delivery.

**Concept CL2** assumes the development of several CLTs on the rim of the central city zone. These centers aside of warehousing and consolidating the delivery of goods, would develop different VAL services, reverse logistics, home delivery, delivery to special zones for the delivery of goods (pickup points) etc. The transport of goods from farther locations GTC in Batajnica or warehouses on the rim of the central city zone to the closest CLT would be by road transport, while cargo trolley would circulate between CLTs. The distribution of goods from the CLTs to the generator in the gravitational zone would be done primarily through the use of small and eco-supply vehicles.

**Concept CL3** represents the beginning of a complex city logistics network with two GTCs on the rim of the city and four CLTs on the rim of the central city zone. The aim of the GTCs is the cessation of long distance road flows, while the

purpose of the CLTs is the consolidated delivery of goods throughout the city. This concept assumes the use of railway transport between the GTCs and cargo trolley transport between the GTCs and corresponding CLTs. The system of cargo trolley is to be developed also within the central city zone but with the function of supplying delivery to special pickup points and reverse logistics. Between the cargo trolley stops and the generators, the flows would be carried out by pedestrian transport using roll pallets as transport units. In such a way the share of road cargo transport would be diminished in both the central city zone and the city as such.

**Concept CL4** is aimed at the development and application of intermodal transport in CL. It assumes the formation of a network of different categories of logistical centers and heavier use of railroad transport in transport flows at the city level. At Ada Huja a CLT would be developed for the consolidated supply of generators in the gravitational zone along with a terminal for intermodal transport. These two systems have the possibility of connecting with other intermodal transport terminals at other locations by railroad with GTCs at the city rim by shuttle trains. This way a part of railroad infrastructure which passes through the central city zone would be retained but would strengthen the role of train transport in the efficient linking of city zones. From Ada Huja a circular cargo trolley line would be used for the flows between CLTs. The distribution of goods in the gravitational zone of CLTs would be done through the use of small supply eco-vehicles.

Each of the mentioned concepts has certain advantages and disadvantages and each requires the support of local governments in the planning and implementation and mostly of all in the defining of urban plans and regulation.

Financial structures and refunding mechanisms are wide subjects of research that have many direct applications and usages in urban transport, mainly in infrastructure and public transport planning. However, those subjects are much less common in urban logistics. This can be explained by the cohabitation and usually the conflicts between public planners and private operators. Public planners' aims are directly related to policy assessment, deployment and evaluation. Private operators goals deal mainly with carrier-based planning tactics and strategies. But, in any case, it is necessary to provide funds for investments, for both public and private entities.

There are four refunding approaches: (i) collective utility; (ii) users' refunding, and (iii) a wide variety of mixed approaches. Earlier it was

considered that the first two approaches are in direct conflict, but the development of mixed approaches show that they can make a good combination and may improve the economic viability of a project [10].

Collective utility can be defined as the socio-economic interest that a project can bring to a society [11]. From the point of view of collective utility, the initial investments and operational costs are paid by public authorities. That means that financial resources have to come from the public through taxes, local or national, without any requested monetary return. To justify a public utility, an investment has to be approved as socio-economically viable. User's refunding strategies consist of making the user pay for benefiting from the system or the service, more precisely charging transport carriers, retailers and/or shippers a fee for using an urban logistics service.

In combined approaches in urban logistics, the main refunding systems are mixed because the investment costs are difficult to be refunded entirely. For that reason, public authorities accept to partially finance them, then to make them operational and economically viable.

The most common strategy is that of private funding with public intervention. In this case the public authority does not have an economic benefit with its financing contribution. Indeed, public bodies do not get refunded, but help private stakeholders to make the projects economically viable, assuming that the public utility justifies a partial collaboration in funding without asking for a return.

There are three main forms of public intervention [12]:

- Delegation is the way in which public authorities cover a part of the investments and give a private company the means to make a service. Sometimes, like in public transport, they cover a part of operational costs, in other cases they cover only the investments and give free usage of the structures, but the operational costs have to be covered by the private company.
- Subsidies represent economic assistance that does not need to be refunded. Such support can be direct or indirect. Direct subsidies are in general under public market regulations and follow a system of calls. Several public bodies propose direct subsidies: for example the European Commission via several support programs, each country national institutions, regional bodies, local bodies or non-governmental associations. Indirect

subsidies in indirect ways help to decrease some costs, for example price of real estate in the city central zone. Some experiences from several cities point out that this projects ceased operations once subsidies dried up.

- Public loans is the case of low interest credits to help the development of urban logistics systems. This economic assistance must be refunded back to the public authority but interests rate are in general indexed directly to inflation, so that they are more convenient than commercial loans.

Public Private Partnerships are popular in public transport. They are mentioned more and more in connection with City Logistics projects. A better and deeper knowledge of this financing model would dampen the scepticism regarding its application including in Beograd.

Only strong financial support, as for example a subsidy to cover investment costs, has a positive impact in stimulating system use and fee payment. In any case, such results need to be discussed with the concerned stakeholders, both public and private, in order to reach a consensus. To do this, further work to implement decision support tools will lead to the integration of multi-criteria methods into economic analysis.

#### 4. CONCLUDING REMARKS

City logistics as an overall optimization process should be understood as one of the key components of urban sustainable development. Much work still has to be done on collecting the necessary data for acquiring the evaluation of models. City logistics solutions for Belgrade should be discussed among all the involved stakeholders who are expected to find a "raison d'être" to support, apply and finance them.

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## GAINING A COMPETITIVE ADVANTAGE BY INTEGRATION OF MARKETING AND LOGISTICS

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***Abstract:** In today's changing and highly competitive market environment, it is necessary to develop and implement processes that enable better demand fulfilment. Such circumstances dictate the requirements for more responsive way for satisfying the needs, which become crucial for achieving market success. The concepts of marketing and logistics are receiving increased attention as means for gaining competitive advantage. The two main areas of marketing and logistics are: demand creation (marketing) and demand fulfilment (logistics), which should be seen as complementary functions through supply chain management (SCM). The aim of this paper is to highlight the importance of a market-driven supply chain strategy whereby customer value is delivered in the most efficient way. The aim is also to highlight the Supply Chain Management and Customer Relationship Management concepts as key elements for gaining competitive advantage. The successful implementation of logistics principles is shown in the paper on the example of leading international retail company.*

**Keywords:** Competitive advantage; Supply Chain Management; Retail logistics; Marketing logistics; Marketing management.

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### 1. INTRODUCTION

Today's market environment is much different in comparison to what it was just a few decades ago. Companies are today more than ever forced to struggle for their market position, not solely by increasing efficacy of business processes, but also in relationship with their customers.

Basic method for gaining the competitive advantage is by providing goods and services to the targeted customers better than the competition, but at the same time, providing increased value for the customers. As author Porter says competitive advantage fundamentally arises from the value that the company is able to provide to its customers. Simultaneously, such value must not exceed the costs of its own creation by the company, as it would not be profitable for the company [12].

Marketing concept, in its core, supports this kind of customer oriented philosophy by putting the customer in the centre of every business activity. What do matter for marketing are opinions and desires of analysed customer, as they have the leading impact on business process of one company.

Therefore, the value is what customers are willing to buy and in return give some amount of their money.

From all stated, it follows that competitive advantage could be achieved by offering goods and services at lower prices than the competitors', or by offering special conveniences for customers at the premium price.

Even though single companies are trying to acquire and keep satisfied customers in their portfolio, that is not sufficient in today's market. Huge supply chains are emerging in the market, which by its size and strength exceed output that single company can provide to the customers. Such supply chains are competing among each other, strengthening the links between members of the supply chain, and by that trying to achieve competitive advantage, increase loyalty of their customers and provide greater value than the competition. Described supply chains in general are constituted by following members: manufacturers, distributors, wholesale and retail and at the end the most important member, customer.

In such environment there are two major concepts that contribute to success and profitable managing of the supply chain and those are:

marketing and logistics. Earlier, the connection between those two has been weakly understood and recognized. Some authors say that the convergence of marketing and logistics is based upon simple model with three key areas that need to be connected. Those are the consumer franchise, customer value, and the supply chain [2]. Customers are becoming more and more demanding, and they expect higher level of delivered services, where the time as factor has become critical factor in the process of gaining competitive advantage.

Challenge for the organization that seeks to become the leader in providing services to its customers is to recognize requirements from different segments of customers and to restructure its logistics process around the achievement of those requirements. Differentiation through superior customer service offers an opportunity to avoid price competition, which eases the path to competitive advantage.

The aim of this paper is to show importance of a market driven supply chain in order to gain competitive strength. Also on the example of leading international retail company it will be shown how combination of marketing and logistics can lead to great market success.

## 2. MARKETING AND LOGISTICS

Many industries have arisen lately based on time compression, from over-night delivery to fast food. Technology additionally speeds up this process through innovations. Communication resources allow answering on customer demand faster and more convenient. That is the reason why logistics, as one of the functions that manages flow of goods and materials from production place to place of consumption [8], must not lose responsiveness in spite of heightened risk of both stock-outs and over-stocked situations [2].

Definition of logistics management as some author state is the process of planning, implementation and controlling the efficient, effective flow and storage of goods, services and related information from point of origin to point of consumption [8]. Even more, logistics is not confined just to manufacturing operations, but is also very relevant to all enterprises, governments, hospitals, schools, and service organizations.

Marketing on the other side, in its core oriented toward the customer, tends to deliver increased value to its customers. In that direction increasingly are used tactics of relationship management (CRM), which guide companies toward long-term and profitable customer in the future. Nevertheless,

solely use of marketing tactics in building customer loyalty and brand awareness in the market, are becoming insufficient for achieving competitive advantage. Together, with synergetic effect of quality managed marketing and logistics, companies and supply chains can come to efficient, cost acceptable, and what is more important from customer point of view expected and satisfying service, better than competition.

As confirmation of previously stated fact, more and more present phenomena in retail stores is that even though brand is strongly developed in the mind of the customer (by marketing activities), if the product is not in the stock or on the shelves (logistics activities) and at the same time there is present a substitute brand, customers will in most cases turn to the other product. This indicates that logistics part of business achievement is greatly important in overall market performance. For that is credited qualitative supply chain, which implies that every member of chain adds something more to the value of the product or service, and contributes to the final satisfaction of customer.

Some of the factors that are key for the development of logistics are: 1) Development of information technologies; 2) Globalization of markets; 3) Fast development of global container network; 4) Development of free port and free trade zones; 5) Addition of value to the product through the global logistic network,... etc. [1].

## 3. SCM IN MARKETING LOGISTICS

The importance of marketing-oriented logistics can be found in the simple statement that the delivery is tailored to the requirements of not only the segment of customers, but also to individual customers. Integration of marketing and logistics in the supply chain management provides a comprehensive control of products and services flow through distribution channels.

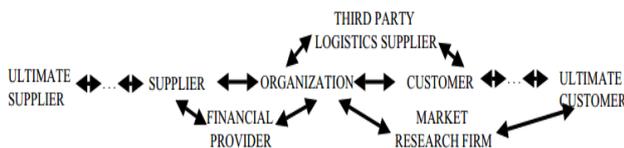
Economic development and market changes create a number of new logistics concepts. As an instrument of retail marketing, logistics must be sufficiently flexible to be able to adapt to these changes, especially in those parts which were initiated and created by consumers' needs and desires.

"Management is on the verge of a major breakthrough in understanding how industrial company success depends on the interactions between the flows of information, materials, money, manpower, and capital equipment. The way these five flow systems interlock to amplify one another and to cause change and fluctuation will form the

basis for anticipating the effects of decisions, policies, organizational forms, and investment choices” [3]. Although this definition is about half a century old, it can be said that Forrester identified key factors of management dynamics that underlie today's concept of Supply Chain Management (SCM).

Summarizing many definitions from different authors, SCM can be defined as “a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer” [10].

Considering that there is no universal configuration of the supply chain and that there are countless alternatives, it is important to know that any organization can be a part of many supply chains. For example, *Tesco* may be part of the supply chain for confectionery products, for electronic devices, clothing and many other products. With regard to marketing-oriented logistics concept, the end consumer should be considered as a member of the supply chain. This is important because the retail chains are gaining in importance in the upstream and downstream flows that constitute the supply chain.



**Figure 1. Ultimate supply chain\* (\*Source: adopted from Mentzer et al., 2001)**

Supply chains can vary from simple and direct, with a single agent between suppliers and consumers, to highly complex and indirect, with a lot of participants in this process. Successful realization of flows from the suppliers through the customers (which is represented in Figure 1) involves the delivery of value and security of customer satisfaction, which can be achieved through traditional business functions (marketing, sales, research and development, forecasting, production, procurement, logistics, information technology, finance, and customer service). Also, the figure shows “the role of customer value and satisfaction to achieve competitive advantage and profitability for the individual companies in the supply chain, and the supply chain as a whole” [10].

The main reason for creating the supply chain is to increase the competitiveness of the supply chain [6][11]. Certain authors [4] argue that it is not common that all activities in the chain (inbound and

outbound logistics, operations, marketing, sales, and service) are run by one organization, in order to increase customer value. Therefore, forming strategic alliances and partnerships in the supply chain (between suppliers, customers or intermediaries) is more and more widespread and it provides a competitive advantage through customer value creation [9]. Competition is not only created among different companies, but among different supply chains and business cooperation.

Improving an organization's competitive advantage and profitability through SCM can be accomplished by enhancing overall customer satisfaction [5]. In this order, there is the opinion that “SCM aims at delivering enhanced customer service and economic value through synchronized management of the flow of physical goods and associated information from sourcing to consumption” [7]. According to Porter [13] “competitive advantage grows fundamentally out of the customer value a firm creates, and aims to establish a profitable and sustainable position against the forces that determine industry competition”. Therefore, the authors believe that implementation of SCM increases customer value and satisfaction, which results with increased competitive advantage (for the supply chain and all its members) and ultimately improves profitability (also of all supply chain members). In order to achieve customer satisfaction, and exceptional customer value delivery, it is very important to build healthy and lasting relationships with them, through quality implementation of Customer Relationship Management (CRM).

The author Ross states that the role of logistics spreads from warehousing and transportation to integrating the logistics operations of the entire supply chain [14]. The same author claims that SCM merges marketing and manufacturing with distribution functions in order to create new sources of competitive advantage. In that sense, customer value and satisfaction help a supply chain to improve competitive advantage and profitability, but that requires more than efficient movement and storage [5]; it requires integrated marketing and logistics management within the concept of SCM.

To summarize the importance of SCM concept in marketing-oriented logistics, we can say that:

- The SCM deals with **improving efficiency** (as reflected in the reduction of cost, time, etc..)
- and **effectiveness** (which refers to the quality of provided services)

- in a **strategic context** (which includes the creation of value and customer satisfaction),
- in order to achieve **competitive advantage** that brings **profitability**.

#### 4. EXAMPLE OF INTEGRATION OF MARKETING, LOGISTICS AND INNOVATIONS AT “TESCO”

Tesco is one of the world largest retail companies which runs business in 12 markets and has more than 500.000 employees. In its market expansion Tesco’s management has decided to enter a South Korean market in 1999. Since then the company has emerged to second largest retailer in the market but with no perspective of becoming number one, because of smaller number of stores compared with the market leader. Due to the specific market conditions some adaptations had to be made. One of those was the name change from Tesco to “Home plus”.

In order to achieve further growth and to become market leader Tesco’s management set a goal to find the innovative solution which would increase the sales without opening new stores. After the conducted market research, gathered information and results were the following. Koreans are second most hard working people in the world, and what is more important, going into the shopping of daily necessities is a dreadful task for them. Hence, problems were in the lack of time for shopping and in the bad attitude of the customers.

Marketers in the company made an innovative solution. If the customers are not willing to go to the store, then the stores should be brought to them. That would ease the buying process and make happier and more loyal customers. In order to achieve the goal, marketers made virtual stores. At the beginning they were placed in the subway stations and later on in some other places where many people were during their working day. In subway stations vivid pictures that represented shelves with the products were placed on the walls and were almost exact imitation of the real store’s merchandising (this is shown in Figure 2). The only difference was that actually there were no products. Under picture of every product was printed a QR code by which the purchase could be made through the internet. In order to use QR code customers had to scan it from the wall picture with their smart phones, after which they could make orders via internet connection. There was no fear that some customers will be left out of possibility to buy in this way, because the vast majority was already in the possession of smart phones with an internet

connection. One of the major tasks that had to be executed by the “Home plus” was logistics and delivery of the products on time and in place specified by the customers. What they made, was home delivery without delays, and with the organized crew who did the job behind the scene.



Figure 2. “Home plus” subway virtual store

The results of innovative approach were the following. Customers could buy the products whenever they wanted, and basically from any place without the need to go to the real store. Efficacy of purchasing was increased for the customers because they had more leisure time to spend with their families or on their favourite activities after working hours. Also the wasted time spent in the public transport was reduced because now it could be used for the shopping of daily goods. After the campaign, on-line sales were increased by 130% from November 2010 until the January 2011, and “Home plus” became number one retailer on the virtual e-market. Furthermore, the main goal was almost achieved because company is now very close second on the South Korean market and is heading towards the leading position. For this campaign company won the “Golden Lion”, significant award at the Cannes International Festival of Creativity.

## 5. CONCLUSION

Market environment is highly saturated with competitors today, which means fast and accurate actions toward satisfying customers. The main goal is to become leader of the market, and to acquire and retain loyal, profitable customers. In order to achieve competitive advantage, companies have to provide to their customers increased value, and not just plain products.

Marketing has already put customer into the core of its focus, by which it can manage long-term customer relationship and fully satisfy customer. But in modern market, it is not sufficient to have only marketing, customer oriented business. It is now needed to have developed network of logistics activities, which combined with marketing activities provide maximum effect.

Until now the connection between marketing and logistics was not well understood and perceived. Supply chains have changed the view, and they are pushing the new kind of competitiveness – competitiveness among supply chains and not only single companies.

This paper has shown some basic characteristics of modern supply chain management, major correlation between marketing and logistics, and most importantly the success that can arise from synergetic combination of marketing and logistics. Also, on the example of *Tesco* (world's leading retail chain), paper has shown that for successful combination of marketing and logistics every company must implement process of innovations.

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## HOW TO START THE HYDROGEN ECONOMY?

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**Abstract:** *The synergic electricity-hydrogen supply network will play key role in the future sustainable transport and energy systems. There are many challenges the prospective hydrogen economy is facing with, especially from the logistics point of view. The first stage can be the Vehicle-To-Grid integration, where electrically driven vehicles are able to download and upload energy from and to the national grid. In the logistics point of view V2G vehicles combined with the B4H box can be the first step in the Hydrogen infrastructure.*

**Keywords:** *V2G, H2G, fuel station network, hydrogen, B4H.*

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### 1. INTRODUCTION

Nowadays the transportation sector is one of the largest energy-intensive sub-systems. As the economies develop, there is an observable increase in the demand for transportation – both in the passenger and freight sub-sectors. The transport sector is, by itself, responsible for most of past and expected future growth of world oil demand, and because transport is 97% dependent on petroleum, these developments could have important impacts on oil markets and carbon dioxide emissions. The transportation sector is consuming the highest rate of crude oil in the world and as time goes by it will be increasing demand for oil.

The transport industry, as a result of globalisation and industrialisation, has not yet become "green" or environmentally friendly, despite the efforts made by the set world policy.

Recently, concerns about air pollution, oil insecurity - suddenly rising prices of oil and especially greenhouse gas (GHG) emissions have been driving a search for an alternative and less polluting new transportation fuels and vehicle technologies in the coming future. The need for a sustainable energy supply is becoming more pressing in the light of declining fossil energy resources, environmental pollution, climate change and the increasing dependency on the oil exporting countries of the Middle East.

On the way of searching for alternative fuels the hydrogen seems to be a probable winner, but there are strong competitors, like bio-fuels or electricity from renewable sources.

The second and third chapter gives an overview about the challenges of the development of hydrogen economy and distribution. Electricity driven vehicle fleets can contribute in the more efficient usage of the existing electric power infrastructure – as will be presented in the fourth chapter. The fourth chapter contains the analysis of the above mentioned hydrogen and V2G infrastructures alongside the main barriers the alternative fuel systems need to overcome. As a conclusion, we can highlight the pathway of infrastructure developments towards green fuel economies.

### 2. INFRASTRUCTURE DEVELOPMENTS ON THE WAY TOWARDS THE HYDROGEN ECONOMY

Hydrogen has for a long time been a well-known secondary energy carrier. The grown interest in the infrastructural use of hydrogen shows that this is a new challenge for mankind to secure the world's energy demand in a sustainable way. The use of hydrogen for energy production purposes competes with the direct use of clean primary energy and/or the use of electric energy based on renewable primary energy. As a substitute for other secondary energy carriers hydrogen is therefore under pressure

of costs and/or must have advantages in comparison to the use of traditional energy carriers.

The literature describes a diverse range of possible futures, from decentralised systems based upon small-scale renewables, through to centralised systems reliant on nuclear energy or carbon-sequestration. There is a broad consensus that the hydrogen economy emerges only slowly. Rapid transitions to hydrogen occur only under conditions of strong governmental support combined with, or as a result of, major “discontinuities” such as shifts in society’s environmental values, “game changing” technological breakthroughs, or rapid increases in the oil price or speed and intensity of climate change.

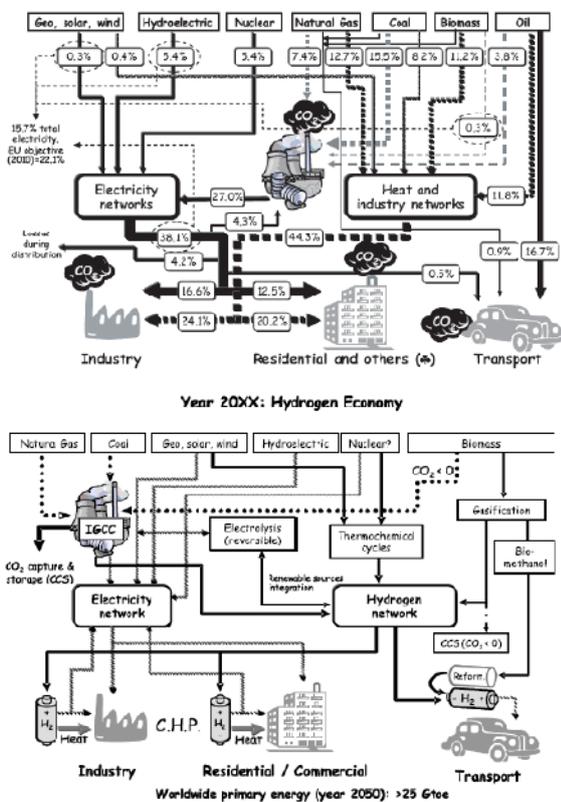


Figure 1. The traditional energy supply and the prospective hydrogen economy [1]

We need Alternative Fuel Vehicles, but there have historically been six major barriers to AFV success[2]:

- 1) high first cost for vehicle,
- 2) on-board fuel storage issues,
- 3) safety and liability concerns,
- 4) high fuelling cost,
- 5) limited fuel stations: chicken and egg problem,
- 6) improvements in the competition: better, cleaner gasoline vehicles.

Considering the chicken and egg problem at the case of alternative fuel vehicles the question appears: What will be the first?[3]

- 1) Costumers will not purchase fuel cell vehicles unless adequate fueling is available.
- 2) Manufacturers will not produce vehicles that people will not buy.
- 3) Fuel providers will not install hydrogen stations for vehicles that do not exist.

### 3. THE HYDROGEN SUPPLY CHAIN

#### 3.1 Hydrogen consumers – vehicles on the road

As hydrogen is one of the candidates of promising alternative fuels, the key element of a chain is missing: we are still waiting for the superior hydrogen cars. There are many new developments on this field, like the Chevrolet Equinox, what is an advanced, fourth-generation hydrogen fuel cell car. The car can go from 0-60 mph in less than 12 seconds and for a distance of approximately 150-200 miles (it is around 240-320 km) per fill-up. [4] In spite of all the efforts it seems that the hydrogen cars will not appear on the European roads in more than 10% rate in next 20 years. On the other hand there are many vehicle types and functions where the hydrogen projects have more chances, like forklifts, trams and public transport buses.

The fuel cell bus demonstration project Clean Urban Transport for Europe (CUTE), which ended in May 2006, was a historical project. It was the first field trial where a substantial number of fuel cell buses of the same kind was operated simultaneously. The objective of the project was to demonstrate and evaluate the new technology used for the Citaro fuel cell buses, including the hydrogen (i.e. fuel) infrastructure. The number of buses as well as the diversity of operation conditions, in addition to the total amount of kilometers and hours driven in the nine participating cities, presents a unique possibility for evaluation of the feasibility of current hydrogen-powered fuel cell vehicles. The nine cities participating in the CUTE project were Amsterdam, Barcelona, Hamburg, London, Luxembourg, Madrid, Porto, Stockholm and Stuttgart. Three buses were operated for 24 months in each city. The aim of the CUTE project, and the chosen design of the bus, was to demonstrate and prove that hydrogen powered fuel cell buses can function in daily operation in urban European transport systems rather than to show the ultimate bus. [5]

### 3.2 Hydrogen distribution and transport

The centrally produced hydrogen can be liquefied and transported in specialized LH2 trailers or ISO containers to the refueling station. In the long-term when larger amounts of H2 can be sold to the market also pipeline systems can deliver H2 directly to the refueling station as today's practice for natural gas. Worldwide more than 1,200 km of industrial hydrogen pipeline systems are in use, some more than 60 years. (hydrogen infrastructure built-up)

H2 can be mixed with natural gas (up to 10%) and transported in existing natural gas pipeline, or it can be transported in dedicated H2 pipelines. H2 mixed with natural gas can be used in existing boilers and furnaces. Pure H2 can be used in fuel cells for electric power, heat, refinery products or distributed to retail outlets for H2-powered vehicles. H2 can also be liquefied and distributed by truck for vehicular use, and natural gas can also be reformed into H2 at retail outlets. This would be a less costly strategy for H2 distribution at the early stages of a H2-based transport system but it would not provide an opportunity for carbon capture and storage.

Also the efficiency is lower than in the case of centralized production. On the short term this efficiency can be 65–70% vs. 75–80%. Over the next decades, higher efficiencies may be reached: 70–80% vs. 80–85%. At last, reforming can take place on board of the vehicle using gasoline, ethanol, methanol or natural gas as the vehicle fuel. If gasoline is used, no changes to the fuel distribution infrastructure are required. However, with gasoline, virtually all of the environmental advantages of fuel cell vehicles would be lost.

It is important to note that hydrogen requires considerably more energy for transportation than existing fossil fuels. H2 transportation by pipeline is hampered by the low volumetric energy density. The pipeline size quadruples, compared to natural gas pipelines. Moreover different materials must be used. Hydrogen transportation by ship is complicated by the very low temperature of liquid H2 (–253°C, 90 degrees lower than for LNG), and a low energy density (liquid H2 has about 40% of LNG's energy density). The boil-off losses amount to 0.2–0.4% per day (but this H2 can be used to fuel the ship) (Abe et al. 1998). High energy requirements and special techniques result in high transportation cost. Therefore international H2 trade is not very likely. It would make sense to locate H2 production closer to consumers (just as oil refineries have been located closer to fuel markets than sources of petroleum). In contrast, transport costs

favour locating biofuels production close to the source of biomass supply rather than fuel markets.

### 3.3 Hydrogen storage

Conditioning: hydrogen has only a low volumetric energy density. Before it is transported or stored, it is therefore conditioned, i.e. compressed or liquefied. This is of particular importance if hydrogen is used in the transport sector, where the tank space is limited and requirements with respect to the cruising range are high. The highest volumetric density is achieved by liquefaction at –253 °C. However, the energy demand involved is quite high. For gaseous hydrogen storage on-board of vehicles, a pressure of 700 bars is state-of-the-art. To allow a smooth refueling process, hydrogen is compressed and stored at 880 bars at the filling station. CO2 emissions result from the use of electricity from the grid (EU-mix).

A number of H2 on-board storage systems have been proposed:

- liquid H2;
- gaseous H2 at up to 800 bars;
- binary metals hydrides;
- carbon nanotubes.

Liquid H2 on-board storage suffers from high distribution costs and significant energy losses. Gaseous H2 has lower energy use for storage, but there is a trade off between vehicle range, fuel tank size and compression energy.

### 3.4 Hydrogen production

Hydrogen fuel does not occur naturally on Earth and this is not an energy source; rather it is an energy carrier. It cannot be extracted like natural gas or oil, but needs to be released by applying energy. On the one hand, this represents a drawback because the process requires the input of primary energy carriers like coal, natural gas or biomass, electricity or high temperatures. On the other hand, the advantage is that a wide range of different feedstock's and energy sources can be used for hydrogen production. It is a new challenge for a mankind to secure the world's energy demand in a sustainable way – but there are several questions which still waiting for answers.

It has to be stressed that hydrogen is a final energy carrier like electricity or gasoline, so that the question of primary energy carrier demand is not solved by using hydrogen. The goal for future energy systems must be the development of clean and affordable new primary energy sources, not new energy carriers. All the same, hydrogen could be an important new energy carrier – for example in zero

emission fuel cell vehicles or in E-hybrids (what could contain a Bio-Gasoline internal combustion engine with electrical generator and power electronics, a fuel cell box and different types of electrical and chemical accumulators).

H<sub>2</sub> could be fed directly to appliances containing small fuel cells or burnt to provide heat or hot water. In this scenario, H<sub>2</sub> would compete with electricity as a clean energy carrier in all sectors. However, while H<sub>2</sub> might offer some potential full fuel cycle efficiency advantages compared to electricity, the high investment cost needed to compete with a distribution network that already exists would be a severe impediment to expanding H<sub>2</sub> use in this direction. H<sub>2</sub>, however, faces no established CO<sub>2</sub>-free alternative for motor vehicles. While some alternative fuels have penetrated some niche markets (LP gas, natural gas, ethanol, methanol, and electricity), taken together, they account for less than 1% of worldwide gasoline and diesel fuel use.[6]

We can produce hydrogen in a different ways, from different raw materials and with different procedure.

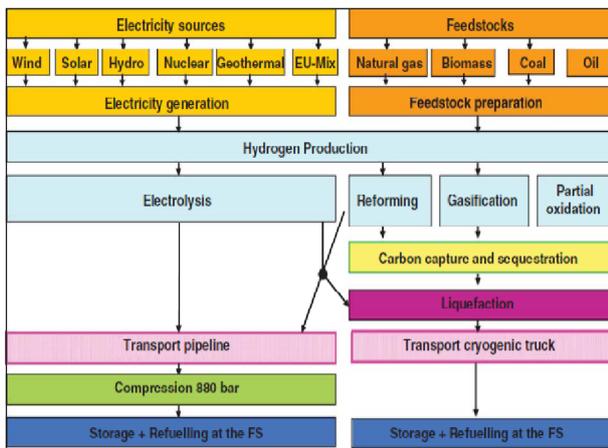


Figure 2. Sub-system of hydrogen pathways [7]

#### 4. V2G – VEHICLE –TO –GRID

As future electricity and transport sectors will be coupled in the hydrogen economy, we have an also promising concept today for electrically driven vehicles. Vehicle-to-grid (V2G) technologies represent a potential opportunity to bring forward and accelerate a transition towards electric-drive vehicles by improving the commercial viability of new vehicle technologies [8].

##### 4.1 The concept

The V2G concept involves using parked vehicles to supply generation services to the electricity grid. The V2G concept is one of the attractive ideas to

synergize the electricity and the transportation sector. This concept with pure electric and hybrid-electric vehicles (which are capable to connect to the grid and load/unload electrical energy) could help to manage electricity resources better, and it empowers vehicle owners to earn money by selling power back to the grid when parking, depends on the current fuel/electricity prizes.

One factor which suggests such benefits may exist relates to the fact that private vehicles are parked on average 93–96% of their lifetime, during which time each represents an idle asset. Each parked vehicle contains underutilized energy conversion and fuel (or battery) storage capacity, and may actually create negative value due to parking costs. Accordingly, generating V2G power from parked vehicles can better utilize an expensive investment (particularly in the case of new and alternative vehicle technologies), thereby enabling cars to provide both mobility and energy services. Since average vehicles in the US travel on the road only 4–5% of the day, and at least 90% of personal vehicles sit unused (in parking lots or garages) even during peak traffic hours, the existing 191 million automobiles in the United States would create 2865GW of equivalent electricity capacity if all the vehicles supplied power simultaneously to the grid — an unlikely occurrence, because this amount is more than twice than the total nameplate capacity of all US electric generators in 2006.



Figure 3. V2G system design [9]

##### 4.2 Type of cars

There are a new upcoming technology in the transportation and power sector - Plug in hybrid electric vehicle PHEVs. These technologies include hybrid-electric vehicles (HEVs), fuel cell vehicles (FCVs) and battery electric vehicles (BEVs). Collectively, these options can be categorized as

electric-drive vehicles (EDVs), because they all have the capability to produce motive power from electricity, rather than from the internal combustion engine.

These vehicles has a battery storage system of 4kWh or more, you can recharging a battery from an external source, and you are able to drive at least 10 miles (160 km) in all electricity mode. These vehicles are able to run on fossil fuels, electricity, or a combination of both leading to a wide variety of advantages including reduced dependence on foreign oil, increased fuel economy, increased power efficiency, lowered greenhouse gas (GHG) emissions and vehicle-to-grid (V2G) technology. In the market the best example for this car is the Toyota Prius this vehicle could originally be converted from a hybrid electric vehicle (HEV) into a plug in hybrid electric vehicle (PHEV) using an aftermarket kit and is now being manufactured as a both a HEV and PHEV.

The superiority of electricity-driven vehicles (trains, trams, trolleys, forklifts) both in their performance and environmental impact is widely accepted. Apart from the electricity-driven vehicles, the infrastructure for their use is also rapidly developing, such as chargers and battery systems, smart parking and charging stations [10].

## **5. LOGISTICS SOLUTIONS FOR SOLVING THE PROBLEM OF LIMITED RANGE**

The main barrier of electric vehicle penetration is the limited range. It is still a question if the final solution is the hydrogen car or not. There are two different types of solutions for the problem from the logistics point of view: quick charging or on-board generation.

The BMW i3 car was designed for urban mobility. The 170-hp electric motor, which twists out up to 184 lb-ft of torque, receives its power from a 22-kWh, liquid-cooled lithium-ion battery. Thanks to the optional SAE DC Combo Fast Charging hardware, that battery can fill to 100 percent in about 30 minutes. The 220-volt Level 2 J1772 charger, meanwhile, takes care of business in about 3 hours. The motor works in concert with a single-speed transmission to send power to the rear wheels. The i3 uses regenerative braking to help keep the battery running as long as possible. In a research project, which involved 1000 participants and more than 12.5 million driven miles, BMW found that the average daily driving distance was around 30 miles (48 km). When viewed through that prism, the i3's 80 to 100 miles (129 to 161 km) of range looks more. BMW says that ECO MODE can add an extra

12 percent. In addition to the all-electric version, buyers can choose to equip the i3 with a 34-hp 650cc range-extending two-cylinder engine, essentially turning the car into a Volt-like series hybrid. That engine will not power the wheels but will serve strictly as a back-up power reserve, adding range and versatility [11].

The Tesla Roadster is a battery electric vehicle (BEV) sports car produced by the electric car firm Tesla Motors in California. The Roadster was the first highway-capable all-electric vehicle in serial production for sale in the United States in recent times. Since 2008 Tesla had sold more than 2,400 Roadsters in 31 countries through September 2012, and most of the remaining Tesla Roadsters were sold in Europe and Asia during the fourth quarter of 2012. The Roadster was the first production automobile to use lithium-ion battery cells and the first production BEV (all-electric) to travel more than 200 miles (320 km) per charge. The world distance record of 501 km (311 mi) for a production electric car on a single charge was set by a Roadster on October 27, 2009, during the Global Green Challenge in outback. According to the U.S. EPA, the Roadster can travel 244 miles (393 km) on a single charge of its lithium-ion battery pack, and can accelerate from 0 to 60 mph (0 to 97 km/h) in 3.7 or 3.9 seconds depending on the model. To charge the hall battery is takes 3 and half hours but the Tesla Supercharger recharges Model S quickly. Superchargers are for refueling quickly on road trips. A Supercharger can charge about half the battery in 20 minutes. All Model S vehicles with the 85 kWh battery can use Superchargers as can properly equipped 60 kWh battery vehicles. Tesla has a 8 years battery warranty for the 85 kWh battery and it is with unlimited miles.

The B4H (box-for-hydrogen) concept is not a technical solution yet, but a special on-board storage and generation method based on the logistics viewpoint we are developing in the frame of our research (in Szabó-Szoba R&D Laboratory, Széchenyi University, Győr). The B4H concept offers to use hydrogen boxes as an on-board filling option in avoiding the hydrogen filling problem. These standardized hydrogen boxes can take place at any hydrogen-electric hybrid car working with fuel cell units. The electricity chain has lower energy losses, and the energy in the battery is excellent for V2G operation (normally there is no need for hydrogen). Users need the fuel cells only if they are travelling more like usual (driving more, than 150km), to extend the range of the car. The B4H boxes are located in the car trunk and connected

with the vehicle hydrogen tank. This box can accept two simple, isolated hydrogen barrels, each of them with 1 kilograms of hydrogen. With this quantity of hydrogen we can drive around 260 kilometres. These boxes and the filling mechanism are controlled by the on-board computer in the car which automates the process. Refuelling do not requires special filling infrastructure at the fuel station, because all the mechanisms are in-built around the hydrogen system of the car. The automated changing of empty tank starts with pushing the change button on the box, when the valve can close automatically. After ventilating and providing secure environment, the box ejects the empty tank. We should put the new 1kg hydrogen tank in the box and it will be automatically attach itself to the system. (The technical parameters of boxes require many innovative solutions we are searching for by using the TRIZ inventive principles. The prize of a box and hydrogen barrel seems to be high – the promise is that we can save a lot by mass production and by more flexible and simple distribution and refuelling cost).

This type of distributed storage and commerce – in the early phase of hydrogen vehicle penetration – is more suitable. Buying a new hydrogen tanks is possible not only at the fuel stations, as users can buy it from offsite machines, and they can leave the empty tanks there as well. Finally it would be much easier and faster to refill the hydrogen tank and continue the trip by using the B4H concept.

## 6. CONCLUSION

Providing sustainable energy systems for future generations is one of the main challenges the world is facing with today. In spite of the promises of the prospective hydrogen economy it is hard to forecast how we should develop the infrastructure we have today – but we can conclude that it is inevitable to investigate the possible strategies from the logistics point of view.

Based on our research we can say that V2G cooperation can contribute in green economy development efforts.

The V2G systems provide deep insights about the nature of cooperation between the vehicles and the national grid, but we need to extend the range of

these vehicles – the B4H concept we got after theoretical logistics research can be one critical stage of future developments.

## ACKNOWLEDGEMENT

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## MODAL DISTRIBUTION ANALYSIS OF FREIGHT TRANSPORT IN REPUBLIC OF CROATIA

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***Abstract:** Intensive modernization of traffic is the main objective of economic development. For this reason, statistical analysis is needed so that transport market could be seen in full and to implement some of the strategies to improve performance of the transport network, which is the main task of transport planning. Therefore, it is necessary to define some key indicators, which primarily show the volume of freight transport. One of the most relevant indicators is the modal distribution or modal split indicator. Therefore, statistical analysis was conducted for the transportation of goods by road, rail, air, pipeline and maritime transport and inland waterways in tons and ton-kilometers. Modal distribution provides the data that enables more efficient and proper utilization of transport network, determination of the dominant mode of goods transport between start and end points, better modal planning and other. Other indicators which are used in this analysis are division on national and international freight transport in tons.*

***Keywords:** freight transport, modal distribution, statistical analysis, indicators, efficient and utilization.*

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### 1. INTRODUCTION

Transportation is an essential part of human activity, and in many ways the basis of all socio-economic interactions. Indeed, no two locations which can interact effectively without a viable means of movement. Thus, a good transport system is essential to support economic growth and development. That is, the ability to transport goods safely, quickly, and cost-effective which is important for national and international market, distribution and economic development of the country. For that reason it is necessary to develop modern technologies in the transport of goods in order to align the quality of service in national and international transport. In order to determine the transport system of some country a statistical analysis with necessary indicators is required. The main indicator which will be used in this statistical analysis of the freight transport in tons and ton-kilometers is the modal distribution or modal split indicator, while the other indicators which are used in this analysis are division on national and international freight transport in tons. Modal distribution is the share of different modes in freight transport from place A to place B. Modal

distribution provides the data that enables more efficient and proper utilization of transport network, determination of the dominant mode of freight transport between start and end points, better modal planning and other. Therefore, statistical analysis was conducted for the transportation of goods by road, rail, air, pipeline, maritime transport and inland waterways. Each mode of transport has geographical, technological and economic advantages in certain situations that can be linked to an appropriate model.

The analysis was conducted by annual rate and average annual rate, using the data of freight transport volume during the period from 2006 to 2012, which are taken from the Croatian Bureau of Statistics. Statistical forms are divided into 14 categories, depending on the thematic group, and for this paper are important statistical reports of Transport and Communications. Statistical report refers to a data on development and state of transport in the Republic of Croatia, and is divided into sections depending on the mode of transport.

### 2. ANALYSIS OF MODAL SPLIT IN FREIGHT TRANSPORT

In order to see the transport market in full statistical analysis is required. The basic analysis is

divided into freight and passenger transport, but for the purposes of this study only freight transport will be analyzed. Furthermore, freight transport can be divided into national and international transport and by mode of transportation, as it is divided in this paper, on the rail, road, air, maritime, inland waterways, and pipelines. During analysis of freight transport, calculation of the annual rate and the average annual rate will be presented. The annual rate of change is relative change of figure value in current period compared to the previous period. It is calculated by the following formula:

$$i_{god} = \left( \frac{promet_{n+1}}{promet_n} - 1 \right) \cdot 100[\%] \quad (1)$$

where is:

$i_{god}$  – annual rate

$promet_{n+1}$  – transport in the (n+1) year

$promet_n$  – transport in the n-th year

The average annual rate of change is relative average change of figure value in the observed period. It is calculated by the following formula:

$$i = \left( \sqrt[n]{\frac{promet_n}{promet_0}} - 1 \right) \cdot 100[\%] \quad (2)$$

where is:

$i$  – average annual rate

$promet_n$  – transport in the n-th year

$promet_0$  – transport in the 0-year

## 2.1 Analysis of the total volume of freight transport in tons

According to Table 1 there is constant decline in the total volume of freight transport during the period from 2007 to 2012, while the increase was only between 2006 and 2007. The decrease in the total volume of goods was affected by the world economic crisis, which was manifested in Croatia in the late 2008 by stopping the growth, followed by a significant reduction in production and consumption, and GDP reduction by more than 6% annually. During that period, the decline in overall demand was primarily affected by reduction in gross fixed capital, which was in the 2011 32.3% less than in the 2008. This unfavourable trend in overall demand led to a reduction in the production of goods and services, which led to a negative trend in industrial production in Croatia in the last four years (2009-2012). The constant reduction of total volume of goods can be seen by reduction index for observed period, which were 0.99 for 2008/2007, 0.88 for 2009/2008, 0.92 for 2010/2009, 0.96 for 2011/2010 and 0.87 for 2012/2011, and by reduction of 33.8% of the total volume of goods transported in the 2012 compared to the 2007, which is followed by a constant decline.

Freight transport in tons in the Republic of Croatia was decreased by 12.3% in the 2012 compared to the 2011. There are fluctuations from year to year in every mode of transport, within the observed period, as a result of reduced economic activity in Republic of Croatia.

The average annual rate of decline in rail transport within the observed period was -5.32%. HŽ Cargo (HŽ Cargo Limited Liability Company for Cargo Transport) in the 2012 reached transport of goods of 11,088 thousand tons, which makes reduction of transport by 5.9% compared to the 2011. The total decline in the freight transport by rail was affected by reduction of international (6.1%) and national transport (4.2%).

An average annual rate of decline in road transport is - 10.5% from 2007 to 2012, so in the 2012 there is 42.75% less transport of goods compared to the 2007. Road transport, which represents 60% of all freight transport, decreases much faster than the available transport capacity, which represents an increasing cost for carriers. Looking at the ratio only between rail and road transport in 2012 in land transport, it is seen that he increased in tons from 13.64% to 14.49% in favour of rail transport.

Maritime transport during the observed period has more or less the same amount of transported goods. Large decrease of 15.53% occurs in the 2012 compared to the 2011. The largest share in the total volume of freight transport has Port of Rijeka, which generates more than 50% of the total freight transport from all ports. The largest decrease is seen in the total transport of bulk cargo - iron ore, coal, stone aggregate, grains and oilseeds, and other bulk cargo (6% compared to 2011). The European transport market suffers from recession, reduced energy consumption industries, thermal power plants are closed or they are operating at reduced capacity, all of which affects the bulk cargo transport. Port of Rijeka, with the Port of Ploče, operate on a transit port services market, in other words transit represent two thirds of the total port transport, mostly goods for the members of European Union. Due to the negative impact of "Schengen regime" and competitiveness from northern ports, an increased decline was recorded. Access Republic of Croatia in European Union will make ports have increased operations, because of the equal market conditions.

In the 2012 only inland waterways and air transport have increased their freight transport compared with the 2011, 14.47% for the inland waterways and 33.33% for air freight transport. Despite their increasing it still does not have a significant impact on the total amount of transported

goods, because of their small share in the overall structure of freight transported. The big increase of the total volume of freight transport by inland waterways from 2007 to 2008 occurred due to the inclusion of transit in the statistical analysis, which

significantly increases the amount of transported cargo. Pipeline transport have constant decline since 2009, which is the most affected by the global crisis in the transport of goods, according to the average annual rate of decline of -9.24%.

**Table 1. Volume of freight transport (in 1000 tons) [11, 12, 13]**

Year	Total	Rail	Road	Maritime	Inland waterways	Air	Pipeline
2006	120.817	15.395	63.840	31.423	1.509	6	8.644
2007	173.661	15.764	114.315	32.420	1.468	6	9.688
2008	171.616	14.851	110.812	30.768	6.415	5	8.765
2009	150.455	11.651	92.847	31.371	5.381	4	9.201
2010	134.985	12.203	74.967	31.948	6.928	3	8.936
2011	129.746	11.794	74.645	30.348	5.184	3	7.772
2012	114.979	11.088	65.439	25.636	5.934	4	6.878

## 2.2 Analysis of the total volume of freight transport in ton-kilometers

A common measure for performance is the ton-kilometers, and it can be used in the analysis of freight transport. Tonne-kilometers is a unit of measure representing the transport of one tonne over a distance of one kilometer.

According to Table 2, in the period from 2006 to 2008 the total volume of goods measured in ton-kilometers has increased. Increase index was 1.01 for 2007/2006 and 1.03 for 2008/2007. After 2008 comes to an expected decline caused by the global crisis, according to the reduce index of 0.95 for 2009/2008, as well as for 2011/2010 and 0.82 for 2012/2011. In 2010 comes to the sudden increase in the total volume of freight transport in ton-kilometers, according to the increase index of 1.16. Growth was caused by the increase within the maritime transport and transport on inland waterways that year. This increase is explained by the increase between supply and demand in the international transport market, and since the Croatians ports are mostly focused on the transit of goods (mostly within the EU), that was reflected in the total amount of goods.

Transport of goods in the Republic of Croatia in the 2012 was decreased by 18.6% in ton-kilometers compared to the 2011. HŽ Cargo in 2012 has achieved transport of 2,332 million ton-kilometers which makes transport reduction of 4.35% or 106 million ton-kilometers compared with 2011. The decrease was affected by the decline of international transport (2.1%) and national transport (9.2%). The average annual rate of decline within the observed period for rail transport was -8.19%. Looking at the

ratio only between rail and road transport, there is increased utilization of road transport in the 2012 in land transport measured in ton-kilometers.

The reason for this is the reduction of economic activity in the building, chemical, manufacturing and automotive industry in Republic of Croatia, which are typical for rail transport. However, the biggest problem in railway transport is poor infrastructure, which especially now after joining the EU should adapt according to European conditions, and offer lower operating and administrative costs in order to gain a part of transport.

During the observed period road transport has an average annual rate of decline -5.42%, while the largest decrease was in 2009 of 17.5% compared to 2008. Road transport is characterized by the largest competition, lots of small, medium-sized and micro-individual carriers, bottlenecks on major road corridors, ecologically least acceptable, one of the most expensive forms of transport and the expansion of the transport infrastructure resulting in loss of habitat. However, despite these facts, notes the dominance of road freight transport in the European and Croatian transport market, which is the most chosen mode of transport.

Within the maritime transport there are some fluctuations from year to year. The biggest decrease was 19.4% in 2012. However, maritime transport has growth potential because of its low congestion, low utilization of Port of Rijeka and ability to reduce needed transport time from the Far East to the EU.

Inland waterways transport also captures fluctuations from year to year, but from 2008 there is big increase in total volume of freight transport, due to the inclusion of transit in the statistical analysis. As already mentioned, inland waterways

transport and air transport have increased their total volume of freight transport in tons, as well as in ton-kilometers in 2012. Air transport has increased by

50% compared with 2011, and inland waterways transport by 11.56% for the same period.

**Table 2. Volume of freight transport (in 1000 tkm) [11, 12, 13]**

Year	Total	Rail	Road	Maritime	Inland waterways	Air	Pipeline
2006	152.127	3.305	10.175	136.994	117	3	1.533
2007	154.370	3.574	11.429	137.474	109	3	1.781
2008	159.849	3.312	11.042	142.972	843	3	1.677
2009	151.942	2.641	9.429	137.345	727	3	1.797
2010	176.795	2.618	8.780	162.751	941	2	1.703
2011	168.972	2.438	8.926	155.437	692	2	1.477
2012	138.650	2.332	8.649	125.678	772	3	1.216

An average annual rate of decline for pipeline transport is -12.2% in the period from 2009 to 2012. Decrease in pipeline transport was caused by stagnation of pipelines capacity through Republic of Croatia.

### 2.3 Analysis of the total volume in national and international freight transport in tons

According to the territorial organization market is divided into national (NT) and international transport (IT), therefore statistical analysis will be conducted per this division.

The railway transport has fluctuations within the observed period in national and international transport. In 2012 the 18.48% of the total volume of freight transport is related to national transport and 81.52% to international transport. The average annual rate of change for national transport is approximately -6%, while for international is almost equal, with amount of -5.18%. The decrease in national transport in 2012 of 4.2% compared to the 2011 was affected by the reduction in transport of iron and steel, minerals (aggregates) and products of plant origin (corn). Only transport of minerals (oil and petroleum products) was increased. In international transport, there is a decrease of 6.1% compared to the 2011. The most significant decline in international transport is recorded in transportation of minerals (oil and oil products), wood and wood products, chemical products, semi-finished wood products, products made of stone, cement and products of plant origin (corn). The increases in transportation are visible in the transportation of minerals (ores) and non-precious metals (iron and steel).

Compared with other modes of transportation road transport only achieves increasing transport in

national transport. One of the main reasons for this is the existence of many carriers in Republic of Croatia, but also a great demand for the transport of goods by road.

There is tremendous growth of 76.87% in national transport in the 2008 compared to 2007, which is followed by a constant decline at an average annual rate of change of -13.27%. International road transport has achieved more or less the same amount of cargo transported within the observed period, but in the 2012 comes to a decrease of 10.16%. After the accession Republic of Croatia in the EU carriers who conducted international freight transport must have license of the Community, in order to continue to conduct international freight transport. In the coming period, it may appear an additional decrease in the international freight transport, because of the embargo on cabotage (2+2 years) for Croatian carriers in the EU members.

Maritime transport has larger share of international transport, with the amount of 96.97% in 2012, while the national transport is 3.03% for the same period. This confirms that the Croatian ports are mostly oriented to transit of goods (two-thirds of total operations). Statistical data in the observed period clearly indicate the effects of the economic crisis that has a negative impact on maritime freight transport in general, especially on national transport. It shows within a decrease of 32.57% in 2009 compared with 2008.

In transport on inland waterways on national transport goes 89.96% of the total transport and 10.04% on international transport. Transport on inland waterways is one of the least used modes of transport, both in the national and international transport. The reason for this is poor infrastructure, poor navigability of river corridors, as well as more

frequent occurrence of droughts and floods. So, there is a decrease of 27.22% in national transport in 2011 due to the very low water levels of rivers that year. In 2012 comes to re-growth of 11.84% in comparison with the 2011. After 2008 there is a decrease in international transport, which is also caused by the global crisis. The average annual rate of change for that period was -5.23%. The biggest decrease was in 2010 of 71.87% in comparison with the 2006, when it was the highest growth.

International air transport was consistently decreasing in the observed period, except in the 2012 when was noted increase in freight transport. The average annual rate of change from 2006 to 2011 is -9.96%. Indicated increase in 2012 is 17.13% compared to the 2011. National air transport has increase by 11.35% in 2007, followed by a constant decline at an average annual rate of change of -14.38%. The highest decrease of 14.5% in national air transport was in 2011.

**Table 3. The volume of freight transport in national and international transport (in 1000 tons) [11, 12, 13]**

Year	Rail		Road		Maritime		Inland waterways		Air	
	NT	IT	NT	IT	NT	IT	NT	IT	NT	IT
2006	2.959	12.436	55.881	7.959	1.273	30.150	189	1.320	1.868	3.769
2007	2.586	13.178	57.926	8.888	1.300	31.120	163	1.305	2.076	3.572
2008	2.617	12.234	102.457	8.355	1.176	29.592	5.676	739	1.767	3.369
2009	2.406	9.245	85.358	7.489	793	30.578	4.975	406	1.286	2.542
2010	1.996	10.207	67.126	7.841	797	31.151	6.558	370	1.049	2.148
2011	2.167	9.627	66.332	8.313	777	29.571	4.773	411	1.117	2.230
2012	2.049	9.039	57.971	7.468	776	24.860	5.338	596	955	2.612

### 3. CONCLUSION

Analysis of freight transport in Republic of Croatia by different modes of transport shows that the current transport system in the Republic of Croatia is not optimal and efficient. It is noted that all benefits of all modes of transport are still poorly used, and the main mode of land transport is transport by road. Transport of goods by rail is not nearly as efficient as it should be, since there are no conditions to take advantage of freight transport by rail. Transport of goods by inland waterways is one of the oldest modes of transportation, and the Croatian inland waterways are also included in the European network of waterways, but they are not sufficiently used for transport of goods. Such state of inland waterways is due to the fact that there was less investment in infrastructure, and for this reason there is a stagnation of this mode of transport in Republic of Croatia. For that reason, river ports excluding cargo handling are transformed into logistics centers. Also there is a very small volume of freight transport in national transport, as opposed to the much larger volume of freight transport in international transport. All data and trends indicate an uneven distribution of transport and definitive dominance of road transport in freight transport at the expense of other modes of transport (maritime, rail, river) that, contrary to European standards and

European policy of sustainable transportation system, belonged in category of more appropriate, desirable and sustainable in a mass cargo transport. Since there was an increase in the 2012 in the freight transport on inland waterways and air transport compared to other modes of transport, such data can be taken as a small but positive step in terms of turning all types of cargo from roads to other modes of transport. Given that this situation causes traffic congestion, especially on the major trans-European corridors and in urban areas, it is mandatory to deal with the problem according to the principle of regulating competition between the various modes of transport. Otherwise, road freight transport could achieve a monopoly on freight transport in the European Union, and this imbalance would enable growth and the development of intermodal transport, which is a priority of European transport policy.

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# ONE APPROACH TO THE DEVELOPMENT OF MODELS OF LOGISTICS OF TOURISTICS COASTAL REGIONS

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**Abstract:** The research presented in this paper is model of logistics of coastal tourist regions that presents special and unique tourist area with a number of smaller towns and tourist resorts. In order to eliminate all that is unnecessary in the process of implementation of logistic flows imposed the idea of enhancing the existing solutions of distribution system, so that at the end result was the development of a win - win situation of all parties in the logistics chain. Exploring the relationship: space → logistics centers and terminals → location problem → optimization of supply of tourist facilities is basis for the development of the model. The paper presents the possible variants of sustainable modes of regional travel.

**Keywords:** Logistics, tourist region, model of logistics.

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## 1. INTRODUCTION

Coastal tourist regions (CTR) in their evolutionary development path dominantly incorporated spatial and historical component, with all the characteristics in terms of: (i) the close association with the water surface, (ii) dense urban cores with a concentration of generators of logistics activities within them, (iii) narrow one-way streets weighted implementation of freight transport, (iv) the congestion on the approach roads at certain intervals, (c) the predominance of road transport mode of shipping goods, (vi) the desire to find an adequate model of supplying the city center and tourist resort and that it does not undermine the quality of tourist offer and environmental area. Because of pronounced regional metabolism of all processes and activities, especially those in the field of logistics, CTR require new solutions that can adapt to the newly developed situation.

In recent years, more and more the focus is on models of sustainable regional development, which promote integration of regional forms, incorporating the logistics into tourist offer, more decisive guidance on the use of combined mode of distribution and concept of environmental sustainability. This model essentially opposes road pro-freight transport strategy that has long been present and encouraged the increase in the number of delivery vehicles on the road especially per year, initiating the series of negative environmental influences.

## 2. THE ESSENCE OF THE TERM MODEL OF LOGISTICS

**Term of model of logistics** (MOL) presents the [4] form made on set of principles, first of all logistics (Figure 1.) for optimal connection of primary logistics elements and secondary logistics elements aiming at the development of new tenable system's and conceptual solution of regional logistics.

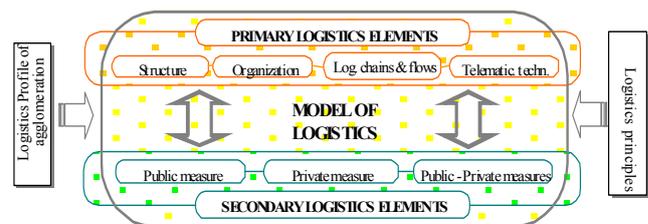


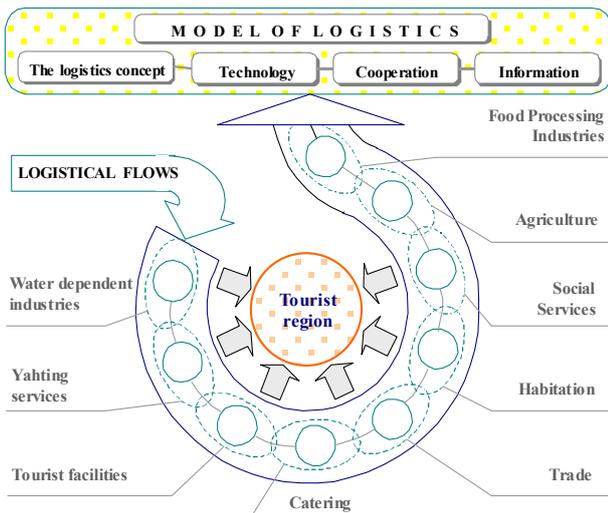
Figure 1. Graphical representation of the MOL [4]

Model of sustainability is closely connected to the total logistics integration (TLI) process in a geographic area. Founder of spatial economics Von Tienen (developed model of concentric zones in 1826.) made the first serious attempt to explain the differences in the heights of land rent and land use, binding to the factor of sites comparing to the city center. In accordance to Tinen's theory, we can conclude that the CTR factor of sites in relation to the water surface is the key element of the model. On this basis, the geographic area in CTR the closest to water surface, and presents the area with the highest density, the highest rents and the highest traffic intensity. As a rule, these spaces are reserved for the most expensive tourist facilities, while the

most distant geographical areas with the lowest rents are used for industrial or agricultural production, where transportation costs are lowest one, and the intensity of transport is considerably weaker.

How TLI creates sustainable, competitive, strategic advantage, it must be approached to the reaffirmation of the spatial aspect of the CTR in accordance to Tinen model. Descriptive approach to research of relationship: *geographic area and associated generators of logistical requirements* → *logistics centers and terminals* → *location problem* → *optimization of supply of tourist facilities presents the basis of research.*

Quality management of TLI system essentially should represent searching for the optimum between four processes [7]: (i) research and forecasting of customer needs and expectations, (ii) cooperation, coordination and consolidation of material, energy, transport, information flows, (iii) network and spatial planning, (iv) environmental planning.



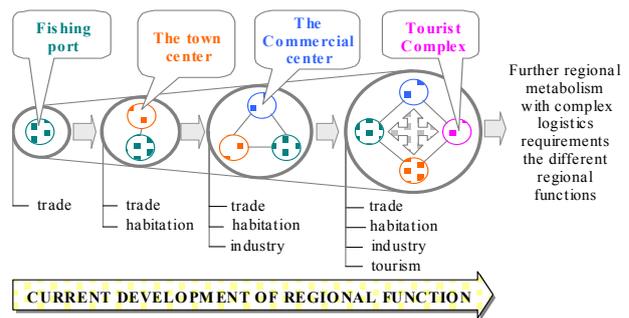
**Figure 2. Tourism region and its integration** (The author's creations)

Pronounced regional metabolism affect the existing logistics solutions, initiates higher costs and more complex problems related to the processes of physical distribution of goods. Applying complex approach aimed at minimizing transportation requirements and the development of cooperative models of physical distribution were never seriously considered. Therefore, the development of new methodological approaches to create sustainable solutions to regional logistics imposed itself as an inspiration and a necessity.

### 3. APPROACH THE DEVELOPMENT OF A MOL

CTR in its evaluation development (Figure 3) crossed the four developmental stages. Each of these

stages of development depending on the degree of development of society had attended a logistics solution. The characteristic of the fourth stage of development, there is a process of regional metabolism that has its future development trend. In addition, there is a concentration of a number of regional function in a relatively small space, which intersect with each other creating a series of negative effects that harm the sustainable development of the region. Its economic prosperity experienced by only those regions that have a better logistics solution.



**Figure 3. Evaluation of tourism regions** (The author's creations)

Limited infrastructure capacity on the one hand and the increased frequency of vehicles on the other hand, create a number of obstacles to the realization of commodity flows. Regions that are in the initial stages were oriented to trade and housing, are now faced with an increasing number of tourists. The former of confrontation and refraction of commodity flows such as ports, harbors and squares in the city, have now become a major tourist and gastronomic places where there has been a change in the characteristics of commodity flows in terms of size, intensity and structure. The key problem is that there has been an increase in road transport products [10]: (i) elimination of holding stock in the facilities, (ii) the desire to deliver the goods by the JIT strategy, (iii) a sharp increase in B2C commerce, and (iv) to independently solve problems of transport of some subjects not taking into account the overall efficiency.

A common feature of all development phases of tourism in the region is the need for the supply and distribution of goods whose intensity changes over a period of years. What separates CTR are size, shape and physical characteristics of commodity flows. In addition, the difference is the way of distribution of goods. Once the goods was brought directly to the water, and later after the technological progress that was from the mainland, and more recently to look for adjustable solution that would take advantage of both modes of delivery and distribution.

### 3.1 Principles of development MOL

Because of its multidimensional influence on the business, development of MOL has to be based on the application of system's approach using the next relations: *preparation* → *analysis* → *synthesis* → *control*.

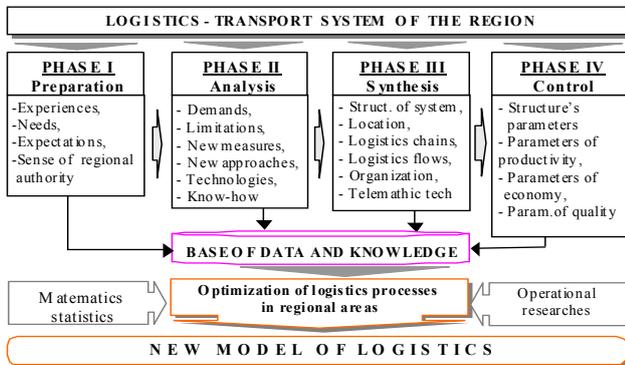


Figure 4. Course of development MOL [4]

The development of new system's solution also should be based on:

- output of multicriteria's analysis,
- output of model of optimization where time and cost are the main components,
- planning of activities on the process model,
- using top-down or bottom-up approach, as well as using both approaches during the decision making,
- application of logistics controlling as a concept that enables integrated assistance to decision making,
- application of some measures that will enable adjusting the gap between public and private sectors,
- application of integrated logistics service (ILS),
- development of the model for multicriteria's evaluation of possible solutions.

### 3.2. Conditions for the development of regional MOL

**Conditions 1** The tendency for TLI in a CTR is basically related to the process of development of logistics centers (LC) organized (Figure 5) within or outside the seaport.

Their function [10] is to create the preconditions for: (i) concentration of all logistics activities on one space without the duplicating of capacities, (ii) coordination and cooperation between some links in the logistics chain, (iii) specialization of the work of logistics systems, (iv) marketing approach and market animation, (v) proposal of logistics services on one space, (vi) high quality of logistics service, (vii) application of environmental acceptable technologies

of transport. LC imagined and organized on this way, present central elements and base structure – the hardware of the MOL.

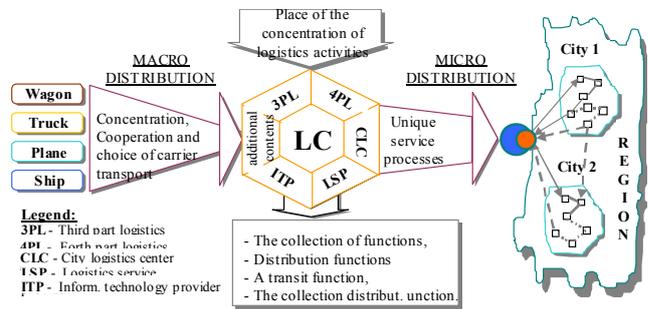


Figure 5. LC a place of concentration [4]

The decision model that incorporates a large naval port with LC and several smaller ports and harbors along the coast of a CTR, is a good basis for developing a network of cross docking terminals and transfer from macro to micro trade flows, which are implemented by the demands of tourism entities. Cross docking terminals in combination with small fast boats, which carry small containers delivery from the sea, ecological and commercial vehicles that distribute goods in containers or on pallets in the tightest of urban areas on the mainland side, are the key technological elements of the solution.

**Condition 2.** The use of new logistics strategies (LS). Their orientation is focused on time synchronization and the implementation of new types and forms of cooperation, integration and specialization in logistics. LS provide quality input for strategic decisions, requiring detailed analysis and research in order to find an adequate response including questions such as: (i) logistics activities and the scope of organized within the LC, which left logistic providers, (ii) the form of organizational forms applied between LC and 3PL and 4PL, (iii) what is the optimal degree of cooperation in terms of investment, cost, quality and delivery reliability, and (iv) the form of management applied.

**Condition 3.** Many obvious problems in the logistics processes, especially in transport process cause demands for the application of modern logistics measures, which (Figure 6.) should contribute to development of new tenable conceptual solutions.

**Conditions 4.** The existence of logistics professionals, capable to implement and maintain the MOL.

### 3.3. Possible solutions to the MOL of CTR

All so far developed MOL are trying to achieve satisfaction of set goals with the goals of efficiency, economy, quality of service and protection of the environment stand out as primary. Level organization

of logistics processes necessary to facilitate the implementation of a supply chain should be resolved by applying adjustable MOL, through a variety of his possible solutions (Figure 7).

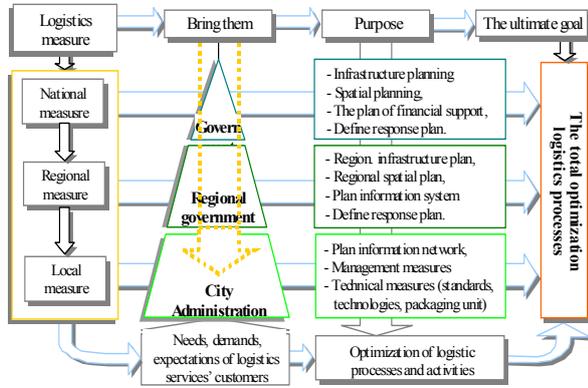


Figure 6. Representation of measures in the logistics [4]

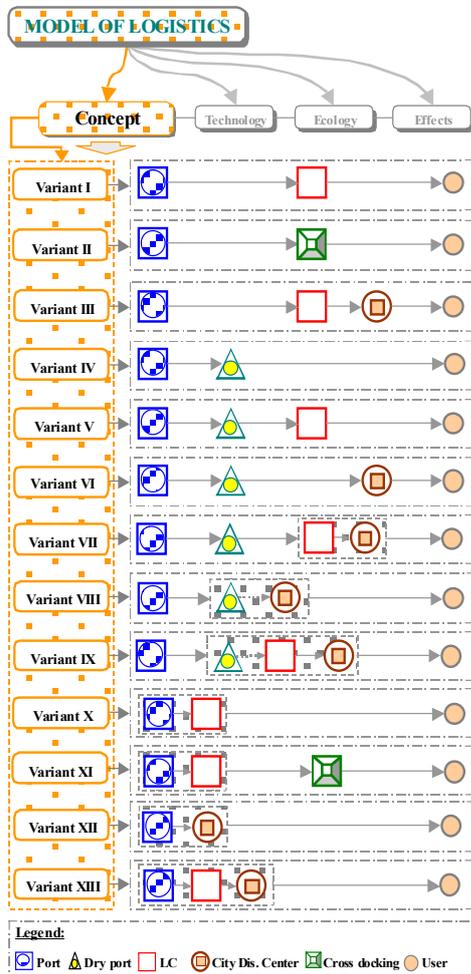


Figure 7. Variety of logistics solutions for model CTR (The author's creations)

#### 4. MATHEMATICAL RESTRICTIONS IN MODEL

The key objective of the model is to minimize total facility and transportation costs. Further:

- Does not assume each site has the same fixed costs;
- Does not assume that sites are capacitated;
- Does not assume that there is a set number of facilities  $p$  that should be opened;

Determines optimal number and locations of facilities, as well as assignments of demand to a facility.

#### 4.1 Clustering generator

Grouping of generators on the following principle is necessary to define the possibility of developing cross docking terminals: (i) select a distance measure, (ii) select a clustering algorithm, (iii) determine the number of clusters, (iv) validate the analysis

Defining distance: the Euclidean distance

$$D_{ij} = \sqrt{\sum_{k=1}^H (x_{ki} - x_{kj})^2} \quad (1)$$

$D_{ij}$  - distance between cases  $i$  and  $j$   
 $x_{ki}$  - value of variable  $X_k$  for case  $i$

#### 4.2 Defining the conditions and limitations

Including:

- Minimizes total facility and transportation costs;
- Does not assume each site has the same fixed costs;
- Does not assume that sites are capacitated;
- Does not assume that there is a set number of facilities  $p$  that should be opened;
- Determines optimal number and locations of facilities, as well as assignments of demand to a facility.

Notations:

$nf_j$  = fixed cost of locating a facility at candidate site  $j$ ;  
 $nC_j$  = capacity of a facility at candidate site  $j$ ;  
 $\alpha$  = cost per unit demand per unit distance;  
 $nd_{ij}$  = distance between demand node  $i$  and candidate site  $j$ ;  
 $nh_i$  = demand at node  $i$ ;  
 $ny_{ij} = 1$  if demand node  $i$  is assigned to facility at node  $j$ , 0 otherwise.

$$\text{Min} \sum_{j \in J} f_j x_j + \alpha \sum_{i \in I} \sum_{j \in J} h_i d_{ij} y_{ij} \quad (2)$$

$$\text{s.t.} \sum_{j \in J} y_{ij} = 1 \quad \forall i \in I \quad (3)$$

$$y_{ij} - x_j \leq 0 \quad \forall i \in I, \forall j \in J \quad (4)$$

### 4.3 Defining the number and spatial distribution of LC

In this case there are two possible scenarios: (i) the status quo scenario, and (ii) the appointment of new scenario for optimal locations. The current spatial distribution of key LC should be included in the MOL. The new terminal layout should be done using the method of multi-criteria optimization.

### 4.4 The simulation experiment and draw conclusions

Special attention in the MOL focuses on operating processes related to marketing logistics. Marketing logistics is related to the process of ordering and implementation of orders. The transport process as a subsystem of marketing logistics are studied in terms of six basic characteristics of transport requirements, as follows: (i) type of material, (ii) manifestation (iii) place of origin, (iv) law of origin, (c) place of realization, (vi) interval of patience.

The whole problem of simulation modeling is divided into two levels, according to the functions of individual commodity flows: (i) Level 1 refers to the implementation of the macro trends in delivery, (i) Level 2 is related to the process of physical distribution. However it is possible to observe the region one level, it is a matter of choice and present factors

### 5. ALGORITHM FOR DEVELOPMENT OF MOL

Within the algorithm there are identified (Figure 8) the next key processes:

- 1) specify the size of the region,
- 2) clustering generators of logistical requirements,
- 3) defining the structure of the system,
- 4) validation of the solution of simulation modeling.

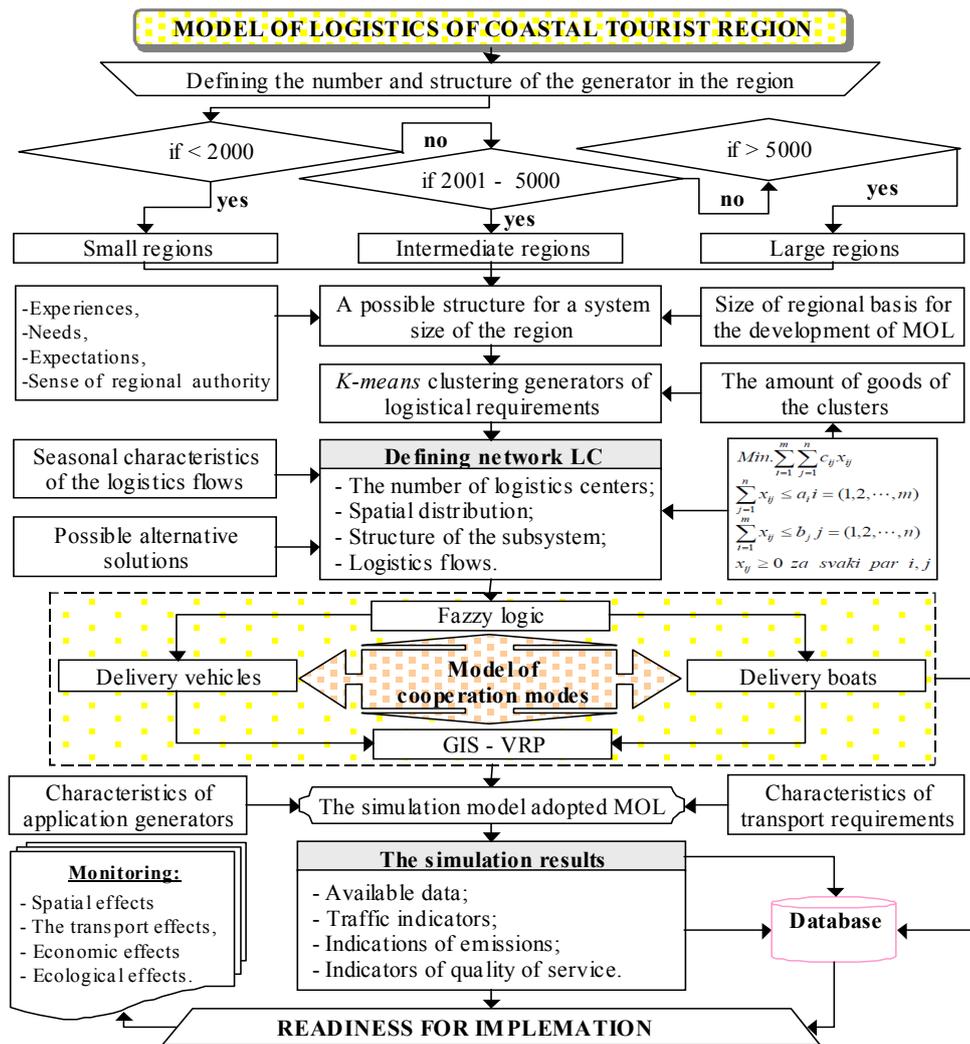


Figure 8. Algorithm for development of MOL (The author's creations)

## 6. CONCLUSION

Interdependence of regional metabolism of sustainable regional development and logistics model CTR gets all close examination viewpoint.

Space restrictions and increased demands for rational operations within specific areas, such as CTR, demand requirements for quality logistics services, including first and foremost, faster and reliable movement of material, transportation, financial and information flows across and within these areas. Although in the past twenty years there have been significant changes in the structure of the food chain, as reflected in the specialization and professionalization of certain LS by: (i) the formation of a network of LC, and the concentration of logistics activities in the same, (ii) reduction of stocks (iii) the application of IT and technology in all links of the chain, (iv) improving information systems and information management, (v) management and control procedures and activities in the logistics chain, etc., it must be said that the increasing fluctuation of tourists, and thus increased volume of trade in tourist regions, requires the development of new models of logistics, especially in the field of system and technology solutions with a focus on optimizing processes within them.

Development of a new MOL for the CTR, requires a multi - step approach to solving of problem. System approach is a good basis for the development of these models. Planning and execution of certain research activities that need to quantify and define the spatial, economic and technical - technological performance of the region in order to develop a form that will allow a total optimization of logistics flows and processes that take place in them is necessary to perform the first stage of development, or in period of system analysis. The development of individual solutions in the model are carried out in two steps, and it would

essentially represent system synthesis. The last stage is simulation modeling as control and verification of the proposed solutions of the effects of the application of the new MOL.

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## ORGANIZATIONAL ATTITUDE TOWARDS INVESTMENT MANAGEMENT IN LOGISTICS

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***Abstract:** This paper shows the current state of investments and their management on the field of logistics. The paper's research is based on a survey that was made using a questionnaire, answers to which revealed some important information that we need to assess the actual state of investments in logistics. In our research we discuss the situation in terms of investments in logistics. We find that in this area we do not have any necessary frameworks, standards or tools to manage them effectively. Furthermore, it has become evident that we are faced with a lack of knowledge and awareness of their importance. The survey also shows that in the terms of investment in logistics there is much room for further development, innovation and change of existing practices. There were some work restrictions during the research as in the volume of work (more time, more people working on the survey and more countries would bring even more confident results), resource, time and finance limitations, the necessary input to achieve completed questionnaires from companies, the lack of understanding investments in logistics and the lack of knowledge. As we show, some companies are rather ignorant to business novelties. The interviewees found it difficult to look at the completed approach to investments where the commercial value (and not technical solutions) is the central concept of an investment.*

**Keywords:** logistics, investments, governance, status report.

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### 1. INTRODUCTION

The main purpose of this article is to present the research of the state of investments in logistics based on a critical analysis. Also some proposals for potential improvements and upgrades of the current state will be presented.

Currently, there is no equivalent research from this area, as this specific area is not well-studied. At the same time we have not found any equivalent research into the state of the art of logistics investment management in the accessible literature. This work shows that it is possible and even necessary to raise investments in logistics to a higher level of management. Its idea is derived from previous research into logistics investments and their role in different aspects of business and its continuity. Research into the effects of investments in logistics as a means of increasing shareholder value can be found as early as 1999, when Walters [1] identified investment management in logistics companies as one of four essential elements of shareholder value planning. Similarly, Lambert and

Burduroglu [2] identified the importance of value creation through investments in the logistics functional area, especially in the view of ensuring that a firm receives adequate rewards for their investments, innovations and performance in logistics (for this, of course the value derived from investments and innovations must be properly measured). Some authors, for example Wagner [3], find that investments, especially those in infrastructure and capital goods, can help logistics companies generate innovative products or services and processes. Finally, the importance of investments in logistics as a building block of efficient logistics is well described by Christopher [4], who sees a continuous programme of improvement, innovation and investments into the logistics framework (consisting of quality, service, cost and time) as a prerequisite to gaining and maintaining logistics competitive advantage.

As a team of logistics researchers we are constantly interested about the position of logistics in organisations in our country and comparing that with other countries in Europe. This interest and comparison are important, because as educators of

the next employment seekers we need to be extensively informed about the role of logistics as much as possible. Besides that our main thought is that investments management in logistics could take logistics to a higher level, which is one of the major goals of this research and paper.

## 2. METHOD

Our survey was based on the method of interviewing with a questionnaire as the main tool of the research. In addition, an analytical approach was included with two most important procedures of analysis and synthesis. The objectives of this research were to present important information, explore the current state of investments in logistics in all of chosen companies in Slovenia and Croatia and to make a critical analysis which helped us to present proposals improvement.

The survey for analysing investment management in logistics covered 42 companies in 2 countries (Slovenia and Croatia), from many different industries, both large and small and also public and private organisations. Our surveyors had to take a balanced and holistic approach with the questionnaire as well as with the process of surveying itself. The questionnaire that we used to interview selected organisations was modelled according to Global Status Report on the Governance of Enterprise IT (GEIT) in 2011 [5].

Val IT was our basics, because according to the article [6], IT and logistics are similar in their position and relation to other processes in an organisation and especially in reference to the perception by the management. The assumption is that the survey from the field of IT can be transferred into logistics with minor modifications because of the significant correlations between both fields.

As we said, the questionnaire that we used in our approach was modelled according to GEIT. The questionnaire consists out of 40 questions on 15 pages, from more general to specific ones. As such, the questionnaire was divided into sections, in our case 3 of them. We were specifically interested in every company's placement (first 9 questions), understanding and knowledge of logistics (from 10th to 20th question), logistics management (with outsourcing, implementation of mechanisms and change of business), innovations and investment management in logistics (Val Log).

One of the presumptions of our research was that the position of logistics depends on characteristics of every organisation. With the first group of questions in our questionnaire (every company's placement)

we had information that we needed to acknowledge the position of logistics. We asked about the role and the working area of the respondent, the function in companies' administration, the sector, the number of employees, the number of employees with degrees in logistics, the income, the companies' structure and the business goals.

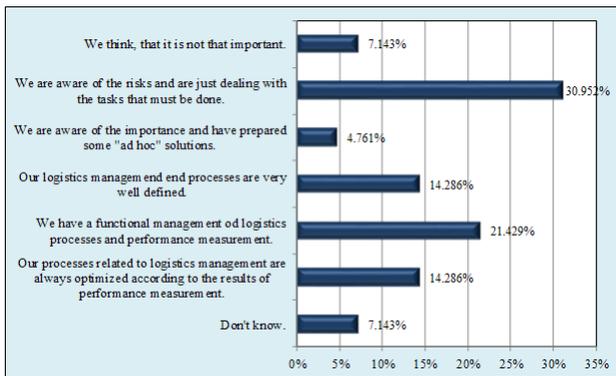
In the second part we focused on the meaning and knowledge of logistics within the company as well as on the organization of logistics, the model of logistics, the role of logistics, potential logistics manager, the impact of logistics on business, projects in logistics, logistics management etc. The data from this part will enable us to establish connections and legality which effect differently organized models of logistics and also investments in logistics.

The third part refers on implementation and management of logistics, outsourcing, implementation of mechanisms, business change, innovation in logistics, investments in logistics or the effectiveness of investment management (as set out in Val LOG – see [6]).

## 3. RESULTS

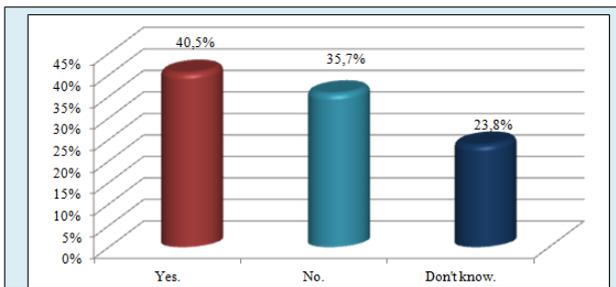
From 42 acquired questionnaires we mostly communicated with the leaders on the strategic level most directly related to logistics, this was the case in 61,7 % of organisations. Mostly, the direct respondents are responsible for logistics or they are a part of the companies' board. The companies are generally from the manufacturing sector (57,1 %), transport and retailing (19 %) and healthcare/pharmacy (7,1 %). 40,5 % of companies are listed among medium-sized enterprises, 35,7 % among large enterprises and 16,7 % among small businesses. Mostly they are privately owned (71,4 %), 21,4 % of them are in the public sector, and 7,4 % in mixed property. The two most important business objectives that companies selected are production efficiency/cost reduction (59,5 %) and service quality (66,7 %).

Below, some specific results of the survey, which we find most interesting and crucial to our research, are presented with charts and explanations.



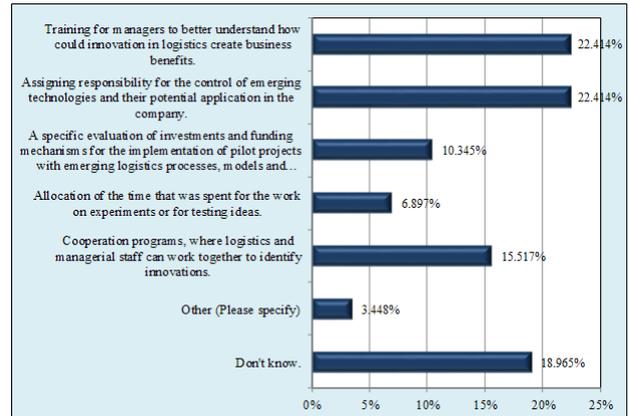
**Figure 1. Question: How would you evaluate the maturity of your business to manage investments in logistics?**

With this question, respondents were required to give only one answer. Almost one third of companies think that they are aware of their risks and are dealing with the tasks that must be done. With 21,429 %, the answer that they have functional management of logistics processes and performance management takes the second place. It attracts attention that 7,143 % of respondents thought that the maturity of business approaches to investment management is not important.



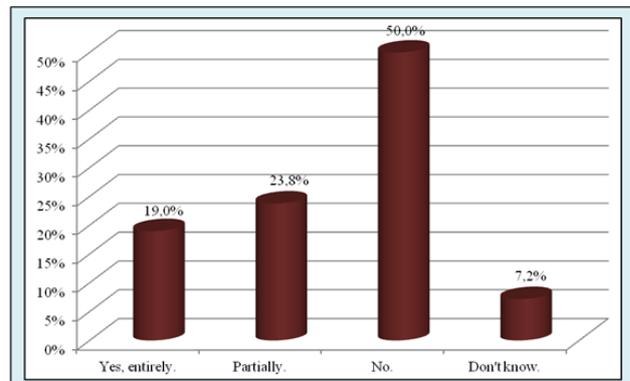
**Figure 2. Question: Are you planning or will you plan to implement any initiative to promote innovation in logistics?**

In contrary to the expectations, 40,5 % of companies are planning (or will plan) to implement some initiatives to promote innovations on the field of logistics.



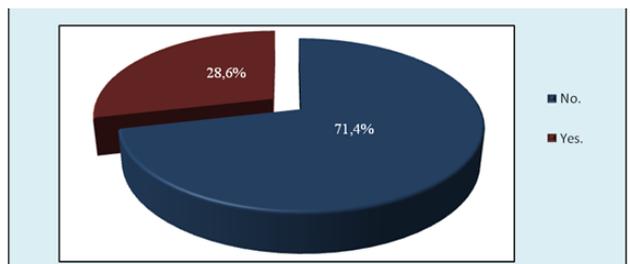
**Figure 3. Question 31: Please specify the mechanisms that have been introduced or you are planning to introduce them in 2012 for the promotion of innovation in logistics in your company.**

This question did not require that only one answer from the respondent. It seem like training for managers (for better understanding of innovation in logistics) and assigning responsibility for the control of emerging technologies are the main two mechanisms that have been (or plan to be) introduced for the promotion of innovations in logistics.



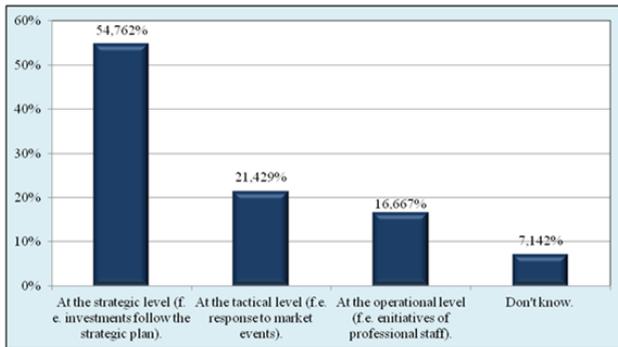
**Figure 4. Question: Do you have an evaluation metric of performance of investments in logistics?**

Half of the companies do not have any evaluation metric on performance of investments in logistics, in addition that 7,2 % of them do not know about this matter.



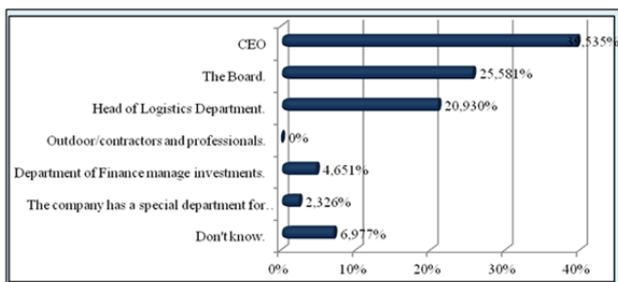
**Figure 5. Question: Have you ever encountered the concept of investment management performance in logistics (Val Log)?**

In contrary to the expectation it looks like Val Log is a distinct expression, 71,4 % of respondents are familiar with it.



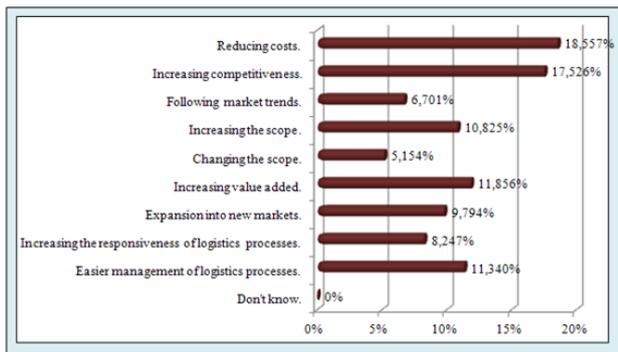
**Figure 6. Question: At what level does your company start to think about investing in logistics?**

Mostly, the strategic level is the one where plans and decisions about investment in logistics are made.



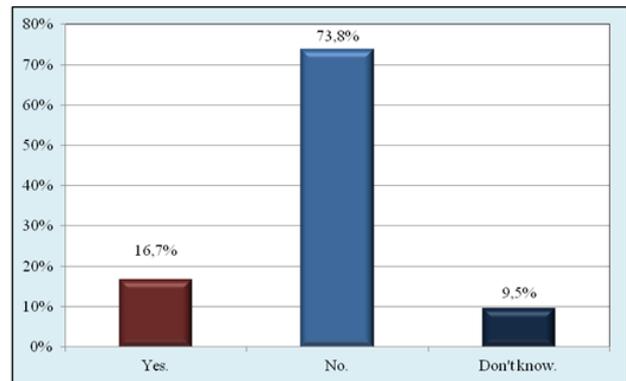
**Figure 7. Question: If your company decides to invest in logistics who is managing or controlling these investments?**

In accordance with this, CEO and the Board are mostly the ones who manage or control investments in logistics.



**Figure 8. Question: What do you think are the main reasons for investment in logistics?**

The most respondents are sure that reducing costs and increasing competitiveness are the two main reasons for investing in logistics (these two reasons were expected given the global crisis situation).



**Figure 8. Question: Does your company use any tools for managing investments in logistics?**

The fact that the question this question was mostly answered negatively shows that companies are not familiar with the tools that can be used for managing investments in logistics (therefore a lack of knowledge in this field is obvious).

#### 4. CONCLUSION

The survey and its analysis revealed a significant degree of accord on the contribution of logistics to business success, the challenges and opportunities connected to logistics, the impact of the economic crisis and views on logistics outsourcing and social networking. The survey findings lend themselves to a variety of conclusions and issues to consider. There are still significant opportunities for many enterprises to transition logistics role to a more proactive one. This can be done through the use of an appropriate organisation structure encompassing roles for managing business relationships and standardised process to effectively bridge the business demand with the logistics supply. Innovations in logistics offer ample opportunities for logistics to play a more pro-active role. The right governance enablers can ensure the transparency of logistics supply and demand and facilitate decision making about demand and its prioritisation on pursuit of value delivery to the enterprise.

The final conclusion is that the position of logistics depends on organisation's size, structure, the model and the role of logistics, the impact of logistics on business, logistics management etc. The survey also showed that the sector (public/private) of an organisation does not particularly influence its position of logistics.

We propose to extend this research in all dimensions. With its extension we could cover more Slovenian companies, and also extend the research to all neighbouring countries as well as increase the number of participating organizations. The survey

can be spread throughout Europe and maybe someday even globally.

This sort of survey can improve investment management and take logistics to a much higher level. In our country and in all the neighbouring states logistics is not as evolved as it could be. We think that the involvement of logistics has a large contribution to the well being of economy and nowadays, in the time of recession is this matter of great importance.

This study has put down a precedent in this area, as the deep insight into the implementation of logistics and its investments has never before been made.

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# STATE OF INTERMODAL TRANSPORT IN CROATIA AND SERBIA

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**Abstract:** *Efficient and competitive transport system is of great importance for the economy of any country, especially due the process of globalization, production of goods and services are increasingly distant from the place of their consumption. In order to achieve socio-economic and environmental sustainability, Europe promotes the use of intermodal transport as a more efficient and cost-effective system for transport of goods. The main goal of this paper is to present and analyze the real situation of intermodal transport in the Republic of Croatia and Republic of Serbia, with regard to the leading EU countries that have high use of intermodal transport. This paper will make a theoretical analysis of intermodal transportation, related to the terminology, development and basic technologies which are used. Analysis of the state of intermodal transport in Republic of Croatia and Republic of Serbia, will be made through the flow of goods and transport corridors which pass through the Republic of Croatia and Republic of Serbia, analysis of the network of intermodal terminals, as well as specific problems that occur, which are related to the legislative, organizational, technical and technological problems.*

**Keywords:** *intermodal transport, intermodal terminal, cargo flows, transport corridors.*

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## 1. INTRODUCTION

The main principle that economy of each country depends on is the development of the transport system and there is a situation that countries with developed industrial production have highly developed transport system. Since the transport costs are increased with globalization, conventional transport is no longer acceptable therefore, a solution is intermodal transport. Development of this kind of transport requires all kinds of transport modes to develop, so that each mode can provide the maximum of its possibilities. Therefore it is very important to know the flow of goods, the condition of the transport infrastructure and network terminals in order that intermodal transport could operate smoothly.

In order to develop a logistics and intermodal transportation system it is necessary to establish and develop the intermodal transport network with logistics centers, which represent a modern connection of different modes and technologies of transportation. Logistics, multimodal transportation network has been largely developed in the European

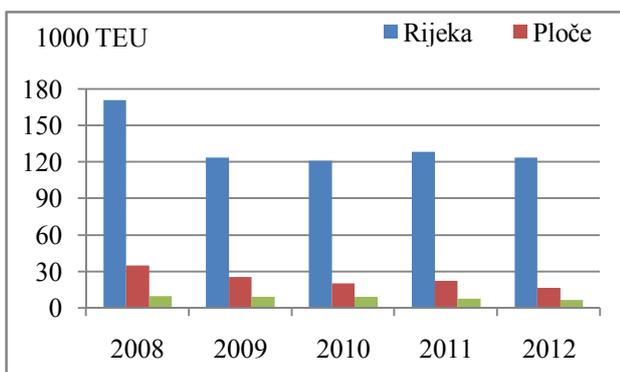
Union (EU). Nevertheless, in the region of the Croatia and Serbia there are many disadvantages related to logistics and transport network, which represent limitation for the application of intermodal transport technologies.

## 2. INTERMODAL TRANSPORT IN REPUBLIC OF CROATIA

Croatia has an excellent geographic location, via connection through V, VII and X corridor associated with the European transport corridors and the ports on the Adriatic it provides the shortest and most economical route that connects Europe with Asia. These are great opportunities for the development of intermodal transport, but the real situation is very bad. The main reason for this is the bad implementation of the transport policy, which has favored road transport through a lot of years, which is well developed, and on the other side a rail system, and a system of inland waterways are completely neglected. For example railway line Botovo-Zagreb-Rijeka, which is important because it connects the Port of Rijeka with the interior of the country, has only one track and because of its

characteristics in the most parts does not correspond to the modern needs of transportation. [2] How the situation is alarming can be confirmed by the fact that the average speed of freight trains in Croatia is only 23 kilometres per hour. Also a big disadvantage of railways is impossibility to provide transport services "door to door" because of lack of industrial tracks. Furthermore, rail freight transport is slow, because it occurs on the same infrastructure as well as passenger transport, where the lowest priority is given to freight transport, being performed mostly at night, which stalls the execution of transportation service. Traffic on inland waterways is in even worse condition than railways. The total length of waterways in Croatia is 804 km, but only 287 km corresponds to conditions of IV class. Devastating is the fact that Croatian rivers annually carry only about 1.5 % of the total volume of goods transported. There are also a large number of laws and regulations that limit future development of intermodal transport. Another problem is the fact that there is no adequate network of intermodal terminals on which can take place transshipment operations. Because of these problems, only 25% of containers from port of Rijeka are transported by rail and 75 % by road. [3]

In Croatia there is no an adequate network of intermodal terminals. As the right terminals we can mention only terminals in Port of Rijeka, Port of Ploče and Container Terminal Zagreb - Vrapče.



**Figure 1. Number of TEU on terminals in Rijeka, Ploče and Zagreb [8]**

Terminals in Osijek, Slavonski Brod and Split we can only tentatively regard container, because of a series of infrastructure characteristics which do not meet the necessary conditions, and small amounts of cargo.

Croatia has the highest trade with Italy and Germany, while Bosnia and Herzegovina and Serbia are the countries with which export is higher than import (Table 2).

**Table 1. Number of TEUs on terminals in Osijek, Slavonski Brod and Split [5]**

Terminals	2010	2011	2012
Osijek	1 179	1 042	695
Slavonski Brod	613	701	873
Split	3 397	3 627	3 642

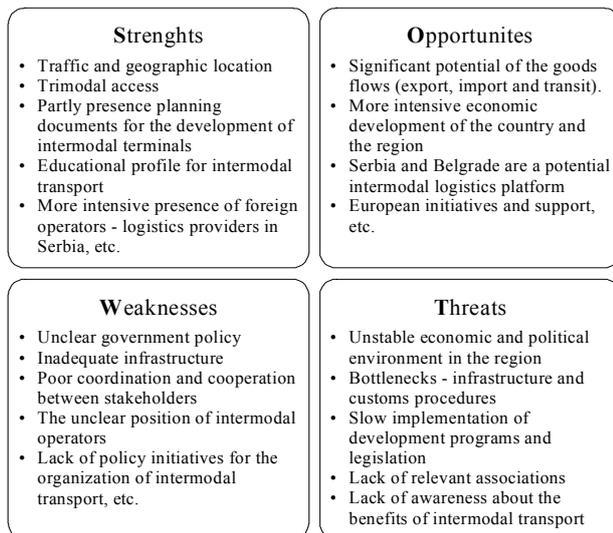
**Table 2. Foreign trade of Croatia with the European countries, 2012 (in 1000 euros) [8]**

Country	Import	Export
Italy	179 299	89 941
Germany	138 490	77 680
Slovenia	67 520	55 678
Bosnia and Herzegovina	34 105	74 151
Serbia	13 566	25 539

### 3. INTERMODAL TRANSPORT IN REPUBLIC OF SERBIA

Geographically, Serbia occupies the central part of the Balkan Peninsula, and from the traffic point of view its position is one the intersection of two Pan-European corridors (road and rail Corridor X and Corridor VII, the Danube River). In this way, it represents an intersection between the south and the north, the west and the east of the Europe. On the other hand, the tri-modal approach allows a higher concentration of flows and their direction towards intermodal technologies. In the past, a network of logistics centres and intermodal terminals has been defined more than once, but the partial approach to the problems did not enable achievement of specific effects. Some of the potentially favourable locations for the development of logistics centres and intermodal terminals have reached a certain degree of physical development, for some has been made planning documents, and some have neither planning nor physical elements of development. [4] Within the project *Facilitating intermodal transport in Serbia*, financed by the European Union, the development of a logistics centre with a modern intermodal terminal in Belgrade is defined. [1] This centre represents a significant development initiative for intermodal transport and logistics in Serbia and the region. In addition, the expected intensification of economic development of Serbia and the region, the growth of export-import and transit flows, European initiatives and support in establishing institutions and harmonization of legislation, represent opportunities for development of intermodal transport in Serbia.

However, despite its great location, the existence of qualified personnel and a number of potentials, intermodal transport in Serbia did not revive. There are still some bottlenecks, and the main reasons are: unclear government policy, institutional and operational problems, inadequate infrastructure and lack of awareness of the benefits offered by intermodal system (Figure 2).



**Figure 2. SWOT analysis of intermodal transport in Serbia**

Institutions are inadequately organized and there are no relevant associations. Coordination and cooperation among stakeholders within the transport chain is weak, the position of intermodal operator is vague and there is lack of political initiative for the organization of intermodal transport. Infrastructure is inadequate and poorly developed, the old machinery and equipment is being applied, and the organization of transport and transport networks is poor. On the other hand, many stakeholders do not have developed awareness of the benefits of intermodal system, and marketing and promotion are inadequate.

Unstable economic and political situation does not inspire confidence, it is slowing down the process of integration of Serbia and the region and it represents a serious threat to the development of intermodal transport in Serbia. Customs formalities with a lot of administrative work create additional costs and complicate intermodal transport. On the other hand, the legislation concerning the transport is significantly improved, and many regulations are in line with European practice. However, the application of the laws is inadequate and slow, especially those related to rail transport.

In Serbia, there are no official statistics on the volume of intermodal transport. Based on research and consultation with operators, it is estimated that

the transport of containers to/from Serbia in 2012 was about 60 000 TEUs. The majority (about 80%) are import containers with goods from Far East, primarily from China. Ports that are most commonly used by ocean carriers in Serbia are the Port of Rijeka (about 70%) and the Port of Bar (20%). A small part of the container flows are realized through the ports of Koper, Constanta and Thessaloniki, while the share of North-European ARA ports is negligible (about 1%). Transport of containers from/to the port is mainly realized by road transport. Rail transport is present only in the realization of flows to/from the Port of Rijeka (20%) and the Port of Bar (10%). The plan is to establish the official line with the block train that will transport the containers between the Port of Rijeka and terminal ŽIT in Belgrade, 2 times a week. The line which would operate once a week is planned between the Port of Koper and Belgrade. In practice, the transit times offered by the Serbian Railways are considered unacceptable and unreliable.

#### 4. INTERMODAL TRANSPORT IN EU

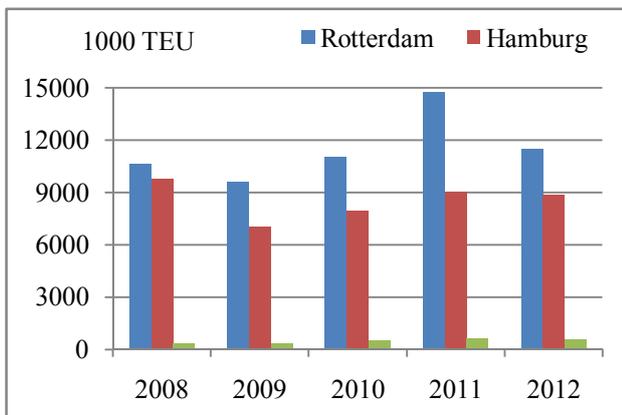
In Europe, intermodal transport has an important role in the transport system, because Europe has realized long time ago the fact that the marine, rail, road and inland waterway transport should act as an unique system on the market, and not to be a competition to each other.

Sea ports are the main generators of cargo flows and intermodal transport, and as the most developed we can mention the Netherlands, Germany, Belgium, France, Spain and Italy. However, the worrying fact is that in the sea ports of the EU-27 loading and unloading during 2010 was about 77,74 mill. TEUs, and in 2011 about 62,84 mill. TEUs which is a decrease of over 19 %. [7]. This becomes even more important if it is known that the container transport at the global level in 2011 increased 5.8 % compared to the previous year. [9] The decreasing trend of container transshipment in European ports is continued in 2012 (about 8 %). [6]

The great advantage of northern European ports is a good rail connection with the interior and developed traffic on inland waterways. In this way, large amounts of cargo can be transported to the end user, with low transportation costs, while there is no congestion on the roads.

For example, in Rotterdam every week about 900 barges are moving towards different destinations. When we look at the railways, in 2007 was opened a track called "Betuwe Route" which is linking Netherlands with the German railway network. It is a double track railway line designed exclusively for

freight traffic, and its capacity is 10 trains per hour in each direction. Port of Genoa is located on the city area, and there are no major opportunities for further expansion, and has a similar problem as Croatian port Rijeka. Because of this, it is connected by rail with the "Rivalta Scrivia" terminal that actually functions as a dry port of Genoa. Port of Koper has almost a constant increase of container traffic, and it is the main port for the Hungarian transit. For the Austrian market it is currently the second port behind the Rotterdam. Basically we can say that around 70 % of freight is intended for transit. [3]



**Figure 3. Number of TEUs in ports of Rotterdam, Hamburg and Koper [6]**

## 5. COMPARISON OF CROATIA AND SERBIA WITH THE EU IN INTERMODAL TRANSPORT

The transport process can be divided into two main parts. The first part refers to the sea route, and if the ship is moving from port Shanghai in China and travels to Rijeka and Rotterdam, theoretically and geographically the fairway to Rijeka is shorter about 6 days. However, it is true and justified only in theory, while in reality it's not like that. In real life, the ship on which there are containers for the Port of Rijeka does not sail directly from Shanghai to the Rijeka, because it stops in several ports, while ships which carry containers to Rotterdam sail directly, or possibly with a stop at one or two transfer ports. So there is a difference of 6 days in travelling and actually Rijeka loses its potential advantage over Rotterdam and other large ports in Europe. Because of this, container road to Rijeka often takes longer than to Rotterdam. [10] But if we look at the part that involves handling of cargo at the port, and transport to the final user Croatia also lags behind Europe. Containers are wasting their time at various depots and warehouses, what is not the case in developed EU countries. With the purchasing of

new machinery, Port of Rijeka could be much more advanced, but that is not enough, because there is still a huge problem with the inadequate state of rail infrastructure and outdated locomotives and wagons which are often not adequate to perform all tasks.

Goods originating from the Middle East, Asia and America, intended for the Serbian market, are unloading in the Adriatic ports, primarily in the Port of Rijeka. Goods are containerized, so there is an interest to keep it that way all the way to Belgrade and other towns in Serbia. Delivery of containers by rail, from the Port of Rijeka to Croatian – Serbian border, is realizing in less than half a day. Although 80% of the distance is reached, most of the containers are being unloaded from the train and stored in Šid, and the goods are being reloaded onto road freight vehicles in order to deliver it by the road to Belgrade. Manipulation is cheaper in Šid than in Belgrade, and road transport lasts for several hours, while transportation by Serbian railways cannot guarantee any timeline for reaching the train station in Belgrade. In practice, the transit times are between 7 and 14 days, and that is unacceptable and significantly worse than road transport. If the working conditions of the Serbian Railways would be better, these containers could reach Belgrade in one day. For this purpose, it is necessary to improve the situation of international railway transport, especially in Serbia. Serbian Railways are working on bureaucratic way and they are uninterested for the concerns of economic subjects. In order to change this, it is necessary to open the market for other rail operators in exploitation field, i.e. to separate the management of infrastructure and operations of transportation. In order to increase the share of rail transport between Adriatic ports and Serbia, it is necessary to promote the transportation with pre-defined times (shuttle type), because regularity of departures/arrivals is the only thing that can attract traffic as competition from road transport is very hard, due to the declining trend of costs and flexibility of "door to door" delivery. In order to keep track of containers, it is necessary to establish more suitable communication links between all chain participants, i.e. connect Adriatic ports, national railways and economic subjects in informational sense.

So the basic lack of Croatia, Serbia and countries in the region is weak correlation with the the hinterland, what means that there is a very bad rail connectivity, which should be the backbone of intermodal transport. An additional problem is the lack of intermodal terminals and their bad connection. In order to overcome the problems, it is necessary to establish promotional centres and work

on associating industrial, commercial, transport and logistics, public and private companies, customs administrations, sanitary and phytosanitary public agencies and other relevant government institutions along the transport, logistics corridors and to form corridor logistics alliances that would build competitive corridor and integrate it into international supply chains.

## 6. CONCLUSION

Trends and experiences clearly show the need, importance, objectives, directions, measures and solutions of development of logistics and intermodal transport. Transport systems in Croatia and Serbia are not adequate for the development of intermodal transport because it was developed without a clearly defined strategy, investments were made only in road transport network, while the railways and inland waterways were neglected. There is no network of intermodal terminals, which are the key points in this system. Analogically to that, logistics and intermodal transport have long been the main factors of economic development, spatial connectivity and market integration in developed countries. EU countries take all possible actions that the majority goods can be transported by rail, inland waterways or sea.

Croatia and Serbia in the last few years try to encourage the development of intermodal transport, but in the moment, there are no large and concrete steps. Exception in Croatia is the Port of Rijeka where the progress is seen, but for which the most deserving is foreign concessionaire. Project and development of intermodal terminal in Belgrade is very important initiator of the development of the

entire economic system of the Serbia and region. Inclusion of Croatia and Serbia into the European transport and logistics system, international goods and transport flows is not possible without the use of intermodal technologies. In this regard, it is necessary to take a series of measures and recommendations that support the further development of logistics and intermodal transport.

## ACKNOWLEDGMENT

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**Part IV**

**MATERIAL HANDLING AND  
WAREHOUSING**

# A TABU SEARCH METAHEURISTIC FOR ASSIGNMENT OF FLOATING CRANES

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***Abstract:** In this paper floating bulk handling cranes have been assigned to serve vessels placed in nodes within inland waterways. The software based on Tabu Search technique is developed for solving the problem. Numerical examples are solved and the results are shown to depict the possibility of the proposed algorithm.*

***Keywords:** Assignment models, Tabu Search Technique, Metaheuristics.*

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## 1. INTRODUCTION

This paper addresses the management of floating bulk handling cranes used for gravel unloading from river vessels into unloading locations.

The entire process of gravel loading, transport and unloading by river towed fleet as well as the allocation of floating bulk handling cranes are controlled by a dispatcher. Decision of dispatcher has to satisfy the interests of all gravel distribution process participants.

The carrier tries to achieve as higher sales at minimal costs. This can be achieved by better usage and minimal hold of vessels as well as by sailing at optimal speed. Interests of handling device owners are the increase of handling device working period and downtime elimination.

In order to minimize time floating cranes spend at these locations, resulting in a higher turnover of available barges in the planning horizon as well as the maximal productivity of the entire system, the loading/unloading system handling devices have to be managed by dispatchers during the process of gravel distribution.

In the paper of Vidović and Vukadinović [7] the problem was formulated for the first time and named the Handling Devices Allocation Problem (HDAP). Handling devices are allocated to the bulk unloading locations minimizing the waiting time of loaded vessels and the execution time of unloading process at the unloading locations.

In the paper of Vidović and Vukadinović static handling devices allocation problem (SHDAP), where all tasks are already known when the

scheduling plan is determined and all vessels to be unloaded are considered to be already placed at unloading locations, is studied. Also, two formulations of the problem are given and heuristics based on clustering is offered for problem solving.

Dynamic Handling Devices Allocation Problem (DHDAP) is a version of the problem where tasks service ready times are known after the beginning of the planning interval.

There are several papers in literature where the DHDAP is solved. Bjelić and Vidović [1] have applied memetic algorithm to solve the problem. Also, Bjelić et al. [2] solved the problem by the Variable neighborhood search metaheuristic.

Although the dispatcher makes real time decisions based on all available information, in this paper static problem is considered under the assumption that the vessel readiness moments for unloading and their capacity are known in advance. The SHDAP was solved by applying the Tabu search technique (TS).

So far, the proposed metaheuristic has not been used for solving the problem.

Numerical example has shown that the TS can successfully allocate floating cranes to tasks.

The paper is organized as follows. The problem description is given in the second chapter. The third chapter provides a description of TS method. The fourth chapter is devoted to the application of the TS to the assignment of floating bulk handling cranes solving. The fifth chapter describes the numerical example and gives analysis of obtained results. The conclusion is given in the sixth chapter.

## 2. PROBLEM DESCRIPTION

Gravel distribution is carried out within inland waterways. The process includes three main phases: loading of gravel by a suction dredger into river barges, transport of gravel to the ports or unloading locations, and unloading of gravel by handling equipment that usually consists of pontoon mounted crane and belt conveyor. Due to high costs, a number of cargo handling devices is usually relatively small, and requires consecutive relocation of handling equipment between different unloading places according to demand.

Since handling devices differ in productivity, their operational characteristics and quantity of load to be handled influence service time at nodes. Unloading time as well as handling device navigation or transfer time between unloading locations must be taken into consideration.

Providing efficient and cost effective service of loaded vessels requires appropriate allocation plan for handling cranes, which means defining sequence of unloading locations that should be served by each handling device. In order to utilize handling devices efficiently, and to minimize the waiting time, as well as the total service time of vessels, it is necessary to consider assignment of handling equipment to unloading locations and orders of servicing different unloading locations.

The problem could be introduced in the following way. For a given collection of barges a set of assignments should be found to minimize total service time including waiting for service and handling devices transfer times.

In other words, sequences of tasks assigned to each of available handling devices should be determined with objective of minimizing the total time that all barges spend on service and waiting to be served.

Waiting time of barges to be served represents the cumulative service time of all barges served by assigned handling device before observed barge. It is assumed that handling devices will serve disjoint subsets of tasks.

In this paper, the static problem (SHDAP), where all tasks are already known beforehand, is studied.

## 3. TABU SEARCH

Tabu search algorithm was proposed by Glover [4] and later by Hansen [5] for solving combinatorial optimization problems. The use of memory, which stores information related to the search process, represents the particular feature of tabu search.

The idea is to start from a random solution and successively move it to one of its current neighbors. Usually, the whole neighborhood is explored in a deterministic manner. When a better neighbor is found, it replaces the current solution. When a local optimum is reached, the search carries on by selecting a candidate worse than the current solution. The best solution in the neighborhood is selected as the new current solution even if it is not improving the current solution. To avoid possible cycles, TS discards the neighbors that have been previously visited. It memorizes moves recently applied, which is called the tabu list. This tabu list constitutes the short-term memory and at each iteration it is updated. Usually, the attributes of the moves are stored in the tabu list. At the beginning, the tabu list is empty and when new elements arrive, previous elements get shifted towards the end of list. When the tabu list is full, the oldest one gets removed from the list. The length of the tabu list determines the tabu tenure, i.e. the number of iterations a certain element is declared as tabu.

Depending on the length of the tabu list, the number of solutions which are unintentionally declared tabu may be very high. This effect makes it difficult for the search process to find better solutions. In such a case it may be desirable to revoke the tabu status of those elements which lead to solutions of outstanding quality. This approach is called aspiration and the most widely used criterion is the occurrence of a solution which exceeds the best solution found so far.

Tabu search incorporates aspects of both intensification and diversification (long-term memory). This is achieved by the combination of the solution choosing mechanism with the tabu list(s). Choosing the best possible neighboring solution in each step clearly aims at intensification. However, the memory has a diversifying effect on the search by disallowing moves or solutions. It may restrict the set of neighbors such that an intensification is not possible any more. This occurs when all improving solutions are marked as tabu. As soon as the search process arrives at an unexplored region of the solution space and unvisited improving solutions are available, it again performs intensification until it encounters the next local optimum [3],[6].

## 4. SOLVING THE ASSIGNMENT OF FLOATING CRANES BY TABU SEARCH

In this chapter the characteristics of the algorithm based on TS methodology will be introduced.

Application of Tabu search technique in software development involves a number of specific choices:

definition of neighborhood and attributes that will be remembered in tabu list, the length of tabu list, aspiration criteria, and ways of combining short-term and long-term memory.

Initial solution is randomly generated and it represents a random sequence of integers in the interval  $[1, N+d-1]$ , where  $N$  is the number of nodes in the network and  $d$  is the number of handling devices ( $d > 1$ ).

A series of numbers  $1, \dots, N$  represents network nodes while the numbers in the series  $N+1, \dots, N+d-1$  are the borders between suborders of nodes assigned to individual devices.

For example, if there is a network with  $N=5$  nodes marked with numbers 1, 2, 3, 4 and 5, served by  $d=2$  handling devices, a possible solution is given in the Table 1.

**Table 1. Solution encoding**

3	4	1	<u>6</u>	2	5
Handling device 1				Handling device 2	

It determines two pieces of information: assignment of handling equipment to nodes and sequencing orders. Number 6 separates node subsets assigned to handling devices. The first handling device is assigned three nodes to serve by this order: 3, 4, and 1 while the second handles two nodes: 2 and 5.

The replacement of any pair nodes in the initial solution changes the orders of nodes assigned to handling devices (depending on the position the assigned subsets might be changed too). It is a neighboring solution, while the described change represents "move". Switched pair of nodes is the attribute of move.

The set of all points in the space of admissible solutions obtained in this way is called the neighborhood of the initial solution. The number of points in the neighborhood is  $\binom{N+d-1}{2}$ .

The developed algorithm combines short-term memory to long-term memory, based on the frequency of memory.

A tabu list  $T$  of length  $L$ , so called the short-term memory, is introduced and it is initially empty. The tabu list memorizes switched pairs of nodes replaced in the last  $L$  moves. A pair of nodes remains on the list next  $L$  iterations and they are forbidden to change the position again.

The neighborhood of the solution expands or reduces depending on the history of the search process and represents the set of all candidates for the next search point. Due to efficiency, only a subset of  $K$  points that give the best value of the criterion function is observed. The next point is determined to be the best permitted point.

The tabu restrictions are not applied in all situations. If there is a forbidden move that leads to a better value of the best current criterion function value, the tabu status is ignored.

When all moves are forbidden and none of them gives better cost function value, the next point is determined by the move losing its tabu status through the minimal number of iterations.

The long-term memory, as an advanced mechanism, stores information, such as frequencies of moves. This type of memory is taken into account when none of possible moves from the current point reduces the value of the criterion function. Then, moves with high frequencies are penalized. Penalization is done by multiplying the frequency by a positive constant  $\omega$ . This value is then added to the value of the objective function.

The next point is obtained by minimizing the value of new criteria functions on the observed set of points.

In this way, the points with the attributes of low frequencies are forced. It is the process of diversification.

In this paper a stopping criterion is given by predefined number of iterations.

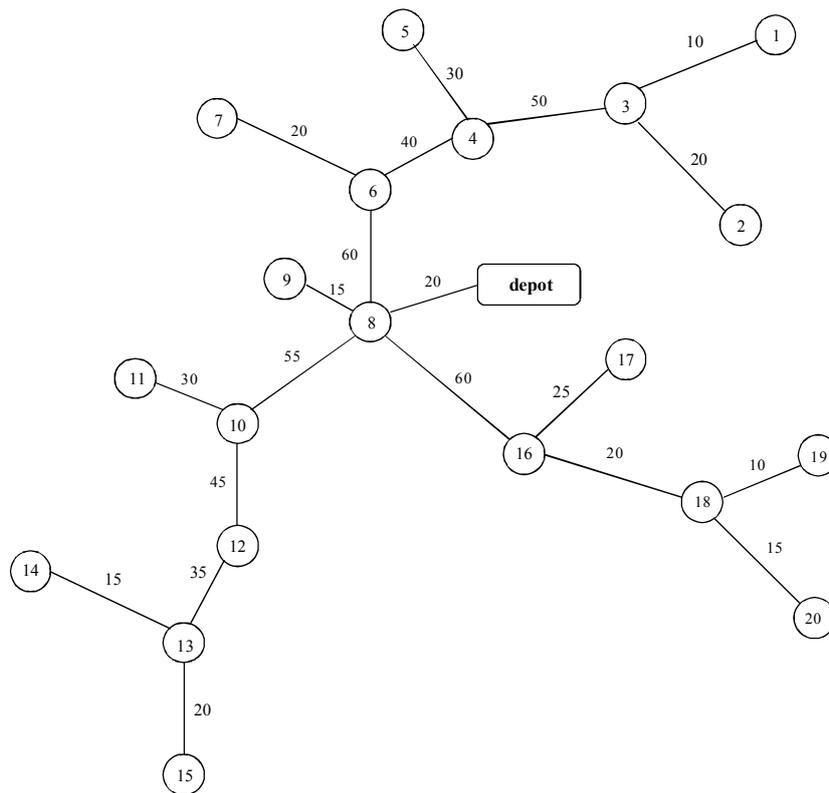
## 5. NUMERICAL EXAMPLE

In order to demonstrate the proposed metaheuristic approach, the following examples are tested.

River and canals network, with distances (km) between network nodes is given in Figure 1. There are twenty unloading locations (nodes) with loaded vessels to be served.

There are three handling devices moving at the same speed, which is 10 km/h. Their unloading productivities are 200 tons/h, 150 tons/h and 100 tons/h, respectively. Handling devices are placed at the depot node.

Handling device preparation times before and after the unloading are considered zero. Also, all vessels to be unloaded are considered to be already placed at unloading locations.



**Figure 1. Transportation network**

The assumption is that nodes have demand shown in Table 2.

**Table 2. Node demand**

Node	1	2	3	4
amount[t]	2000	6000	3000	4000
Node	5	6	7	8
amount[t]	5000	2000	3000	2000
Node	9	10	11	12
amount[t]	5000	3000	1000	2000
Node	13	14	15	16
amount[t]	6000	1000	3000	5000
Node	17	18	19	20
amount[t]	4000	3000	2000	1000

Specific choices concerning developed software were made. A tabu list of length  $L=3$  was introduced. A subset of  $K=15$  neighboring points

that give the best value of the criterion function (as candidates for the next search point) was observed. Attributes of moves stored in the tabu list are switch pairs of nodes. Frequencies of moves were penalized by  $\omega=5$ .

We composed six instances choosing the nodes from transportation network as it is shown in the first column of Table 3. The first fifteen nodes make the first numerical example etc.

All the tests were performed on AMD Athlon Dual Core computer processor with 1.90 GHz and 3 GB of RAM.

All experiments were finished after 100 iterations.

The solutions obtained by using the Tabu search technique are presented in the Table 3.

The objective function values (the total service times) and the CPU times are given in the second and the third column of the Table 3, respectively. Also, subsets of nodes and their orders served by assigned handling devices are given in the Table 3 (column 4, 5 and 6, respectively).

**Table 3. Solution of numerical example**

Set of nodes	Objective function value (h)	CPU time (s)	Handling device 1	Handling device 2	Handling device 3
1-15	1045.83	1.545855	6, 7, 4, 1, 3, 2	8, 11, 10, 9, 5	12, 14, 15, 13
1-16	1201.83	1.761005	6, 7, 4, 3, 1, 2, 5	8, 11, 10, 9, 16	12, 14, 15, 13
1-17	1385.00	2.034951	8, 11, 10, 9, 16, 17, 2	6, 7, 1, 3, 4, 5	12, 14, 15, 13
1-18	1519.00	2.228539	6, 7, 1, 3, 4, 5, 2	8, 10, 18, 17, 16, 9	11, 12, 14, 15, 13
1-19	1644.67	2.441825	8, 6, 7, 4, 1, 3, 2, 5, 9	10, 11, 12, 14, 15, 13	19, 18, 16, 17
1-20	1711.50	2.709223	6, 7, 4, 1, 3, 2, 5	8, 20, 19, 18, 17, 16, 9	11, 12, 14, 15, 10, 13

For example, the last instance consists of all 20 nodes. The total service time is 1711.50 h. The CPU time is 2.709223 seconds. The solution obtained by the software consists of the sequence of 22 integers.

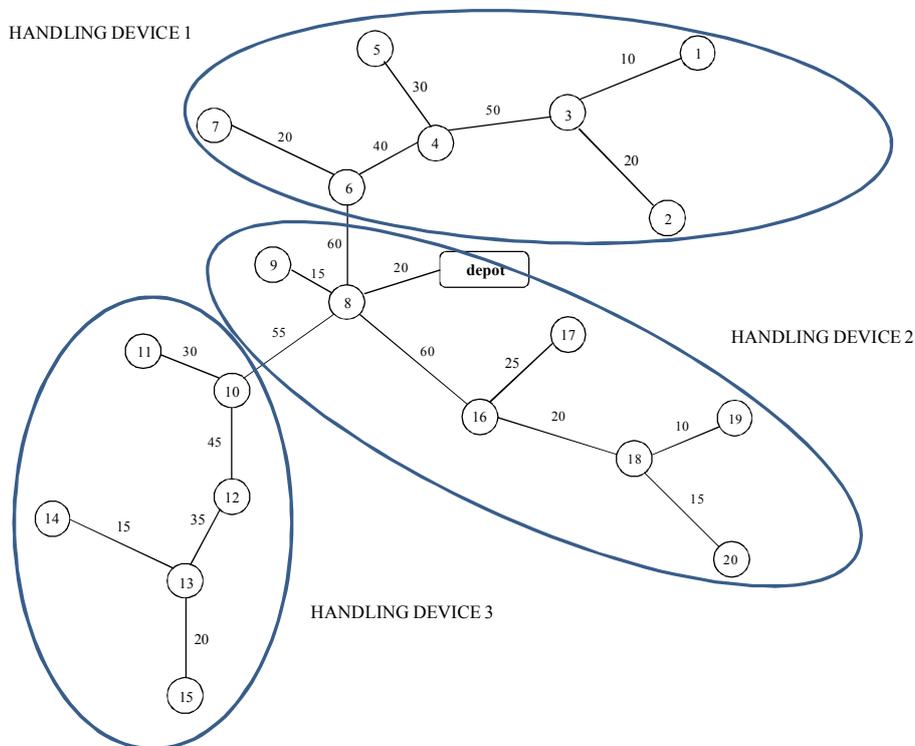
Their order is divided by numbers 21 and 22 on three parts showing the node subset and the order of serving for each handling device. It is shown in the Table 4.

**Table 4. The 20-node solution obtained by the software**

6	7	4	1	3	2	5	<u>22</u>	8	20	19	18	17	16	9	<u>21</u>	11	12	14	15	10	13
Handling device 1								Handling device 2								Handling device 3					

The first handling device is assigned sequence of nodes: 6, 7, 4, 1, 3, 2, 5, the second handling device is to serve: 8, 20, 19, 18, 17, 16, 9 by this order,

while the sequence 11, 12, 14, 15, 10, 13 is to be handled by the third handling device. The solution of this numerical example is given in the Figure 2.



**Figure 2. The solution of the 20 – node transportation network**

## 6. CONCLUSION

This paper addressed the problem of assigning of handling devices to unloading places on inland waterways. Rational handling device allocation enables their better utilization, decreasing costs incurred due to the loaded vessel waiting.

In solving the planned tasks, dispatchers need decision-making system support to make very complex decisions. One of the possibilities for the development of decision support systems is the development of automated systems based on mathematical programming.

Another possibility for the development of decision support systems is the use of heuristic and metaheuristic algorithms that can achieve good solutions in a relatively short time.

In this paper, the approach based on the Tabu search method is offered to address the assignment of floating bulk handling cranes to unloading locations on inland waterways. Six numerical examples (river networks of 15, 16, 17, 18, 19 and 20 nodes) are considered to be served with three handling devices.

Numerical examples have shown that the problem is successfully solved by the proposed metaheuristic algorithm.

Since the computing time of the TS metaheuristic is very reasonable, it is acceptable for solving the problem in real time.

On the basis of obtained results, it could be concluded that the use of this metaheuristic method is justified in solving other resource allocation

problems that might not be exclusively related to the transportation network.

Another research direction might be a development of exact algorithm and a comparison between optimal solutions with those obtained in this paper. Additional research opportunity might be the usage of a real data set.

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## ADVANTAGES OF E-KANBAN SYSTEM COMPARED TO CLASSIC KANBAN SERVING PRODUCTION LINE

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**Abstract:** *In this paper will be analyzed implementation process and upgrade of kanban system from card kanban to e-kanban in real production environment in automotive industry in Lames d.o.o. Previously existed classic card-kanban system was improved by newly developed software which made possible usage of e-kanban system. The software covers only material flow between warehouse and raw material shelves in the production. This software is made in MS Access by authors of this paper, increased flexibility of complete system in the area of production plan changes, packaging changes, and variations of production capacities. There was no need for physical kanban cards printing. All kanban parameters are well connected and related in the database and each change automatically adjusts and recomposes complete material flow between warehouse and production. Also, each step of e-kanban system implementation, detailed comparison between classic kanban and e-kanban systems, and advantages of e-kanban are presented.*

**Keywords:** *e-kanban, automotive, stock optimization, software.*

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### 1. INTRODUCTION

Lean manufacturing has become leading industrial trend in the past few decades. In order to increase its competitiveness and decrease costs, companies are streaming to keep their inventory levels reduced to a minimum while keeping excellent performance and quality of the production [1]. Pull-type production control mechanisms are widely used in automotive industry to control flow of material within the system. Kanban system is the most famous system as one of pull-type mechanisms generally used in automotive industry [2].

Lames d.o.o. is new green field automotive company in Serbia, part of the larger group with several factories located on three continents. The main products of the company are manual and electric window lifters for automotive industry. Lames group is supplier of many major car producers all over the world.

Demanding clients request high quality levels not only for product but also for all processes and organization of their direct suppliers. Lean approach is inevitable in order to achieve such standards.

One of the projects establishing new company was organization of the raw material flow between

warehouse and production line. Like in many automotive industries, kanban concept is mostly used as the best concept for this type of lean production organization.

The main goal was to establish such system which will guarantee optimal stock replenishment of raw material in production shelves without any material shortages which could put in danger production continuity. In the same time, due to limited space in production, excessive stocks would be unacceptable.

### 2. THE FIRST PHASE OF KANBAN IMPLEMENTATION (CLASSIC KANBAN)

Since warehouse software and SAP modules for finished products and production planning do not support electronic kanban, in the first phase of kanban implementation, it was possible to implement classic kanban using cards. Production area consists of three production lines and three subassembly lines used for production of 24 different types of window lifters.

#### 2.1 Calculation of kanban containers

Before start of kanban implementation several parameters have to be defined, such as desired level

of stocks in the production shelves [3]. In our case this level was supposed to be between 2 and 4 hours of production. That means that complete stock replenishment (stock turnover) will occur minimum two times during one production shift. Another important thing is capacity of the line. The higher capacity requires more material in the flow and the vice versa.

In order to define number of containers (kanban cards) which will be used in kanban cycle several other parameters have to be considered. Type of the packaging and quantity in the packaging are the last parameters needed for calculation of quantity of kanban cards needed.

The final formula for quantity of kanban cards is the following:

$$N = (T_{\max} \times Q_{\text{cap}} \times Q_{\text{bom}}) \div Q_{\text{pack}} \quad (1)$$

$N$  – quantity of kanban cards needed

$T_{\max}$  – maximum production time covered with raw material in production shelves

$Q_{\text{cap}}$  – quantity of finished product produced in one hour

$Q_{\text{bom}}$  – quantity of specific material contained in one finished product

$Q_{\text{pack}}$  – quantity of material in the packaging

In case that final result is decimal number, that number should be rounded up.

Taking real example for metal shaft, which is packed in carton boxes containing 250 shafts, for production capacity of 225 final products per hour, each final product contains one metal shaft, and maximum stock coverage of 4 hours calculation would be the following:

$$N = (4 \times 225 \times 1) \div 250 = 3,6 \quad (2)$$

Round up  $3,6 = 4$

$N = 4$  kanban cards needed for stock replenishment of production shelves for metal shafts. Since packaging contains 250 pieces, maximum quantity on the production shelf can be 1000 metal shafts ( $4 \times 250$ ).

In the similar way we can calculate minimum quantity (safety stock) in the production for that material. Previously defined minimum stock for 2 hours of production would be calculated with the same formula:

$$N_{\min} = (T_{\min} \times Q_{\text{cap}} \times Q_{\text{bom}}) \div Q_{\text{pack}} \quad (3)$$

$$N_{\min} = (2 \times 225 \times 1) \div 250 = 1,8 \quad (4)$$

Round up  $1,8 = 2$

$N_{\min} = 2$  kanban cards as minimum stock, or 500 pieces of metal shaft ( $2 \times 250$ )

The kanban calculation of the materials for one finished product can be seen in software application form as well as in the picture below (Figure 1).

**Figure 1. Kanban calculation of materials for one finished product**

After calculation of quantity of kanban cards/containers, all elements for creation of kanban cards are available. These cards follow kanban containers on their way between warehouse and production until consumption of all material in them to feed the production process. The picture of one kanban card is presented below (Figure 2).

Kanban card contains much useful information such as: material code, the name of material and location of the shelf in the production. The card contains card number and total quantity of cards for specific material. In that way it is easy to check if some cards are missing and to establish FIFO (first in first out) system for material consumed in production.

Useful information that can be found on kanban card are also supplier's name, type and dimension of packaging, total quantity in the packaging, minimum and maximum number of containers that can be placed on the shelf in the production [4].

Very useful information for operators on the line is information for which production models the material is used. That reduces mistake of the operator to install the material in the wrong type of product. The picture of the material on the cards reduces possibility to associate any material with the card that does not belong to it. Further to make easier for the operators, cards for different type of products are printed on the different colour paper. If material is used for more than one type of product, its card is printed on white colour paper.

Kanban cards are printed on both sides of the paper and plasticised. Printing on both sides eliminates the need for turning over the card in order to read the information on it. That saves the time for operators and warehouse keepers. Plasticisation prolongs life time of the card and reduces possibility to get dirty and reduce visibility of information printed on the card.

Šifra	<b>32.543.028</b>	Lokacija:	<b>P02-2,3</b>	<b>1 / 4</b>
Naziv:	<b>Kušište</b>	Kartica		
Modeli:	A9, 330			
Naziv:	Drum housing Cartella			
Dobavljač:	O.C.S.A.			
Pakovanje:	Modeli:			
Šifra pakovanja:	854	32.559.000		
Naziv pakovanja:		32.560.000		
Kartonska kutija 600x400x300mm		32.565.000		
Količina u pakovanju - kom	250	32.566.000		
Minimalno pakovanja na liniji:	2			
Maksimalno pakovanja na liniji:	4			
Slika				
ID materijala:	8			

Figure 2. Kanban card

## 2.2 Advantages of classic kanban compared to non-kanban system

After the implementation of kanban cards in Lames d.o.o., many benefits were recognized. Raw material stock control on production shelves was improved. As result of kanban cards implementation the stock was constantly on optimal level between 2 and 4 hours of consumption in production. Out of stock situations were practically eliminated because of improved communication between warehouse keepers and material needs presented with free kanban cards on the shelves. Excessive stock on production shelves was not possible because number of containers is limited by quantity of kanban cards.

In previous system warehouse keepers spent much more time monitoring situation on the shelves, checking each shelf, writing material codes and defining quantity that was supposed to be replenished. Such activities were time consuming and occasionally out of stock situations occurred following frequent communication between warehouse keepers and operators on production lines.

Using kanban cards communication between operators and warehouse keepers does not exist anymore. Free kanban cards are new means of communication. Production operators do not have to monitor material stock levels and can focus on production process [5].

Stock replenishment done by warehouse keepers now is significantly simplified. There is no need for writing any information on piece of paper about quantities needed, material code and position of the shelf on the production floor. All information

needed is written on free kanban card. With that card warehouse keeper can go directly to warehouse to pick up specific material and to return to the position specified on the card.

## 3. IMPLEMENTATION OF E-KANBAN SYSTEM

The advantages of classic kanban are enormous compared to non-kanban systems, but Lames d.o.o. was striving for further material flow optimization and process improvements. The next steps and Lames d.o.o. goal was leading towards e-kanban implementation. But, there were certain obstacles: SAP does not support implementation of e-kanban for the material flow between warehouse and production lines. In order to implement e-kanban, the development of special software was inevitable. New software was developed internally in MS Access and VBA by authors of this paper.

Previously mentioned kanban containers calculation and basics of new e-kanban concept were developed already in MS Access database. Only additional module was supposed to be created that would support material flow with electronic control instead of exiting flow with kanban cards.

Figure 3 presents one part of the e-kanban software that is used in warehouse for stock levels monitoring and stock levels replenishment.

Warehouse keeper monitors the basic screen where all components listed which is needed for current production on the production line. Also stock location is indicated with minimum and maximum allowed quantities on the shelf.

Sifra	Naziv materijala	Pakovanje	Kol. MIN	Kol. MAX	Lokacija	Stanje	SIGNAL	
32.543.028	Kušište	0026	450	1000	P02-2,3	413	-31%	Treb.
32.559.024	Osovina za ručicu	0026	450	1000	P03-4a	694	44%	Treb.
32.559.914	Gornja sajlja podizača stakla	6422	450	1000	P01-1	895	81%	Treb.
32.559.915	Donja sajlja podizača stakla	6422	450	1000	P01-3	921	86%	Treb.
37.011.036	Remenica	0026	450	1800	P02-4	1.540	81%	Treb.

Figure 3. E-kanban form for stock level monitoring

Current stock level on the shelf is visible as well as coloured information about percentage of current stock optimization. If percentage is red, stock level is below minimum stock allowed (the stock is less than needed for 2 hours of production). Yellow colour means that the stock is less than average stock and close to minimum stock. The green colour means that there is still no need for stock replenishment because current stock level is between average and maximum stock (the stock enough for 4 hours of production).

There are two triggers that influence the stock level change. Stock increase trigger is the issue of material from the warehouse, and stock level decrease trigger is printing out of the finished product label at the end of the production line.

Issuing of material from the warehouse is simplified by software. The warehouse keeper just needs to click on the button next to material in e-kanban form which has become yellow or red, and automatically new screen appears with the list of available material in the warehouse in accordance to FIFO system. Next to required material, its location in the warehouse is displayed. With all information available, warehouse keeper has pretty easy job: to pick up needed material at defined position in warehouse and to take that to defined shelf positioned in the production floor.

After issuing of the material from the warehouse, the stock level on the shelf is automatically updated and stock signal is changed from red or yellow to the green.

As previously mentioned, stock reduction occurs permanently as result of printing of finished product labels at the end of the production line. The figure 4 presents how the label looks like.

The printing of label triggers stock reduction of all materials in the production shelves in accordance to the bill of materials defined in the database for each type of finished product.

		FINAL PRODUCT IDENTIFICATION	
Supplier part number (P)	32.559.000	Customer part number	R
		9673153880	
Quantity (pcs)	120	Supplier part number	ALZ. MAN. 5P POST DX
			
Serial number	3790	Work order	1689
			
Date	16.8.2013	Note	

Figure 4. Finished product label

#### 4. ADVANTAGES OF E-KANBAN

Compared to classic kanban system, e-kanban has brought many advantages making easier job for warehouse keepers:

- No need for kanban cards eliminates danger for losing the cards which can seriously harm functioning of stock replenishment system.
- In case of any change in the system (bill of material change, production capacity change) software automatically change

quantity of kanban containers without need of kanban cards printing.

- Control of stock levels is improved due to easy monitoring of the stock levels in the system.
- Warehouse keeper does not have to go to production floor any more to collect free kanban cards. This has reduced working hours of warehouse keeper for 15%.
- Production operators do not have to collect free kanban cards anymore and to place them on the production shelves
- Classic kanban system for some materials cannot be implemented in case that request of minimum 2 containers cannot be met. E-kanban in that situations makes possible to monitor stock levels of such material on the production floor.

#### 5. CONCLUSION

In accordance to Lames d.o.o. statistics out of stock situation occurred two times in the shift in average before classic kanban implementation. After kanban implementation, such situations are practically eliminated. Manpower need was reduced as well. In previous (non-kanban) system 3 warehouse keepers were able to provide stock replenishment for 3 lines. Using kanban cards 2 warehouse keepers are enough to perform the same activities. Further with e-kanban, men hours in the warehouse are additionally reduced for 15%.

Classic kanban sometimes can not include some materials in its system due to some specific reasons. For example window lifter motors because of its big packaging and lack of space on the production floor are excluded from classic kanban. In order to be implemented, at least two cards (containers) should exist for a material, but packaging of motors is too big and only one box can be located nearby production line.

In such situation e-kanban can offer solution because stock level of that material is still visible in the system thanks to existence of two triggers for stock adjustment.

There aren't two identical kanban systems. Each kanban system is tailor made for a specific company. It has to be adjusted to company specific needs and to support material flow and control in the best possible way. Some authors say that kanban is an easy concept to understand and very difficult to implement in the proper way [6].

## ACKNOWLEDGMENT

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# CRITERIUM FOR FUNCTION DEFINING OF FINAL TIME SHARING OF THE BASIC CLARK'S FLOW PRECEDENCE DIAGRAMMING (PDM) STRUCTURE

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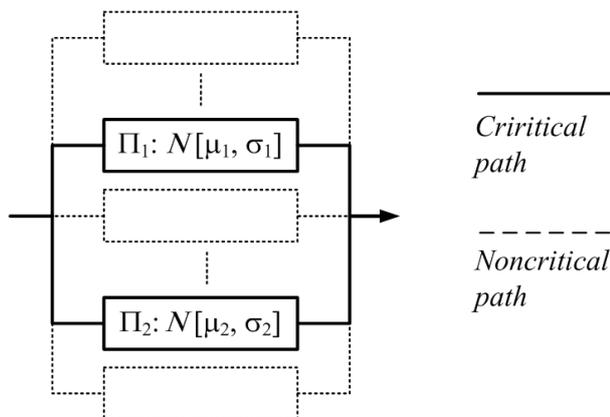
**Abstract:** In this paper the results of the theoretically-experimental researches of the criterion of quantification of the superponed (superposition of two or more values to create a new, resulting activity value) flow time with two or more local - autonomous flows in the network diagram of PDM (Precedence Diagramming Method) type on the basis of Clark's equations are presented. Computational solving of this basic variant of the general flow model through the network is being performed by the analytical and simulated procedures. The mathematical experiment has been realised by the program package Mathcad Professional.

**Keywords:** Superponed function, Clark's model, network plan.

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## 1. INTRODUCTION

The basic model, for which Clark's equation of the equivalent flow has been defined, consists of the oriented graph, where two activities proceed parallelly, have common beginning and flow to one terminal "event" (Figure 1.).



**Figure 1. The flow network with the two locally - autonomous critical flows of PDM structure activity**

In that sense, the activities can be locally - autonomous until they are completely realized. However, they can be interdependent, so Clark's equations were developed for that case, too [1]. In

this work, the results of the basic Clark's equation are being compared with the results of numerical Monte-Carlo simulation. Such basic model with parallel flows of activities and events has a key role in the network planning. Both these methods, the analytical, as well as the numerical one, are characteristic for studying various appearances and processes based on the network models, whether they are the flows of activity, resources, energy, mass servicing, information, technical systems, reliability, emission of nuclear particles etc. Those problems are, as experience shows us [1], of stochastic nature, and it is often impossible to solve them in an analytical way (method), without certain approximation. This way, one network model of the flows of activities is defined and solved, stimulated by the researches of Clark, Styke [2], Dodin [3] and Haga and O'Keefe [4]. That also contributes to developing the algorithm for solving the general model of the critical flows established on the row-parallel structures of the oriented graph. In this analysis, the normal distribution of the endings of some activities with the characteristics of the average value and the adequate time deviation of their realization is superponed.

## 2. THE FLOWS WITH THE CRITICAL ACTIVITIES

The uniform solution of the critical activity flow, and also of the resulting flow time using the expected times of the separate activities, presents one of the most troublesome effects of the network application planning based on stochastic methods. The stochastic (but also the deterministic) networks of activities formed e.g. on the basis of AON (Activity On the Node - the method of the oriented graphs) structure, can be very complex in some cases of planning. The common issues of these flows are: the initial and the final event and the same, approximately the same or different values of the expected time of realization of critical that is, the sub critical flows. The final event will be realized if all the critical flows that "flow into it" have been realized. In that case, one can rightly ask: what is the certainty (as well as probability distribution) that the resulting flow time will be completed in the planned period, considering that such activity graph can contain one, two or an unlimited number of critical flows, primarily of the most complex, i.e. parallel type. To answer this question correctly, it is necessary to define exactly the criteria and the algorithm for the quantification of impacts, primarily of critical and sub critical flows on forming the resulting, i.e. the superponed flow time activities.

## 3. THE AIM OF THE PAPER

The basic aim of this work is the quantification of effects of the two critical flows on forming the resulting, i.e. the superponed flow time. The second objective is setting the criterion for defining the equivalence ( $\equiv$ ) of the parallel flows. By solving it, we create the fundamental base for defining the function of probability distribution, as well as for the noticing of relativity of those flows by applying the Monte-Carlo method, as a control manner.

## 4. THE BASIC TIME PARAMETERS OF THE AUTONOMOUS CRITICAL FLOWS

According to the researches [1], [2], [4] the superposing of intervals of the critical and subcritical flow times and their dispersion and their reducing to one equivalent flow, can be calculated by:

- analytical methods: - Clark's equations for solving the parallel (as well as ordinal) flows,

- and by numerical method – Monte Carlo simulation for solving the parallel and the ordinal flows.

To illustrate the application of the listed basic algorithms, we can use the AON network with two parallel flows:  $\Pi_1$  i  $\Pi_2$  (Figure 1).

### 4.1 The superponed time and the flow variance

In structuring the algorithm for analytical solving of this option of critical flows, one starts from Clark's original equations. These equations solve the parameter flows as follows: the superponed flow time  $T_{1,2}$  and its variances  $\sigma^2(T_{1,2})$ , in the condition of the non - existence of the correlation between the two activities. For the basic oriented graph with two parallel flows, from the initial ( $i$ ) to the terminal ( $j$ ) event (Figure 2) the average value of the flow time,  $\overline{T}_{1,2}$  is:

- The superponed flow time for the independent parallel flows:

$$\overline{T}_{1,2} = \overline{T}_1 \cdot \Phi(\xi_{1,2}) + \overline{T}_2 \cdot \Phi(-\xi_{1,2}) + \lambda_{1,2} \cdot \Psi(\xi_{1,2}) \quad (1)$$

Where:

$$\Phi(\xi) = \frac{1}{\sqrt{2\pi}} \cdot \int_0^\xi \exp\left(-\frac{1}{2} \cdot t^2\right) dt \text{ -is Laplace's integral,}$$

$\Psi(\xi) = \frac{1}{\sqrt{2\pi}} \cdot \exp\left(-\frac{1}{2} \cdot t^2\right)$  -is the function of density of the centred normal distribution, and  $\lambda_{1,2} = \sqrt{\sigma^2(T_1) + \sigma^2(T_2)}$ , that is,  $\xi_{1,2} = \frac{1}{\lambda_{1,2}} \cdot (\overline{T}_1 - \overline{T}_2)$

the parameters of Clark's functions.

In addition, we usually take the expected or the average values of time intervals:  $\overline{T}_1 = \mu_1$  and  $\overline{T}_2 = \mu_2$  and the standard deviations  $\sigma_1 = \sigma(T_1)$  and  $\sigma_2 = \sigma(T_2)$ , so, according to [1], as follows:

- The average superponed flow time:

$$\mu_{1,2} = \mu_1 \cdot \Phi(\xi_{1,2}) + \mu_2 \cdot \Phi(-\xi_{1,2}) + \lambda_{1,2} \cdot \Psi(\xi_{1,2}) \quad (2)$$

- The superponed dispersion is presented by the next Clark's equation:

$$\sigma^2_{1,2} = (\mu_1^2 + \sigma_1^2) \cdot \Phi(\xi_{1,2}) + (\mu_2^2 + \sigma_2^2) \cdot \Phi(-\xi_{1,2}) + (\mu_1 + \mu_2) \cdot \lambda_{1,2} \cdot \varphi(\xi_{1,2}) - \mu_{1,2}^2 \quad (3)$$

By these equations we can describe the properties of one, equivalent flow instead of the previous two (Figure 2.).

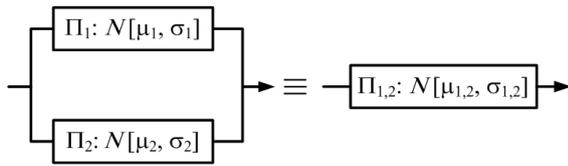


Figure 2. The superponed flow of activities

**4.2 The growth of the superponed flow time in relation to the critical flow**

On the basis of the new superponed function of time distribution  $T_{1,2}$  with the characteristics  $N[\mu_{1,2}, \sigma_{1,2}]$ , the time growth  $T_{1,2}$  can be quantified in relation to the single time  $T_1$  or  $T_2$ , depending on the fact which one of them has a critical feature. For the elementary network with autonomous flows  $\Pi_1$  and  $\Pi_2$ , that growth or the “superponed extract“, after the simpler performing, is:

$$\Delta\mu_{1,2} = \lambda_{1,2} \cdot \varphi(\xi_{1,2}) + (\mu_2 - \mu_1) \cdot \Phi(-\xi_{1,2}) \quad (4)$$

However, in the case of a reversed choice, it follows:

$$\Delta\mu_{2,1} = \lambda_{2,1} \cdot \varphi(\xi_{2,1}) + (\mu_1 - \mu_2) \cdot \Phi(-\xi_{2,1}) \quad (5)$$

In addition to that, the nature of these values is always nonnegative, i.e.:  $\Delta\mu_{1,2} \geq 0$  and  $\Delta\mu_{2,1} \geq 0$ .

**4.3 The testing of the invariability of the flow model**

The testing of invariability should show us if the derived values remained unchanged and uniformly fixed when the flow order in the calculating process was being changed. It is well known that, when dealing with two flows with two parameters each, we can have nine relations for each flow. (Table 1). In other words, when analysing the following possible relations between the expected times and the deviations of single flows, as:

$$\mu_1 \left\{ \begin{matrix} < \\ = \\ > \end{matrix} \right\} \mu_2 \text{ and } \sigma_1 \left\{ \begin{matrix} < \\ = \\ > \end{matrix} \right\} \sigma_2, \text{ where the next relations are considered: } \rho = \left\{ \begin{matrix} < \\ = \\ > \end{matrix} \right\}. \quad (6)$$

Table 1. Combination of relations of the two expected values and two standard deviations

$\mu_1 \rho \mu_2$	<	<	<	=	=	=	>	>	>
$\sigma_1 \rho \sigma_2$	<	=	>	<	=	>	<	=	>

We can conclude that nine different combinations can be formed here altogether.

$$\lambda_{1,2} = \lambda_{2,1}, \quad \xi_{1,2} = -\xi_{2,1},$$

$$\varphi(-\xi_{1,2}) = \varphi(\xi_{2,1}) \text{ and } \Phi(-\xi_{1,2}) = \Phi(\xi_{2,1}) \quad (7)$$

Accepting that:

We get the invariant relations of the basic tested values which are related to the superponed flow, i.e.:  $\mu_{1,2} = \mu_{2,1}$ ;  $\Delta\mu_{1,2} = \Delta\mu_{2,1}$  and  $\sigma^2(T_{1,2}) = \sigma^2(T_{2,1})$  (8)

One can conclude that it is irrelevant which flow of the two observed will be declared as critical, and which one as subcritical. This invariability characteristic of models (4) and (5) is very important for developing the criterion of equivalence of  $w$ -flows [ $w \geq 2$ ).

**5. THE APPLICATION OF THE SIMULATION MODELS**

**5.1 The application of Monte-Carlo method on models with parallel flows**

Let's suppose that the elementary activities of the flow time have normal distribution with the parameters  $N[\mu_v, \sigma_v]$ , ( $v=1,2$ ).

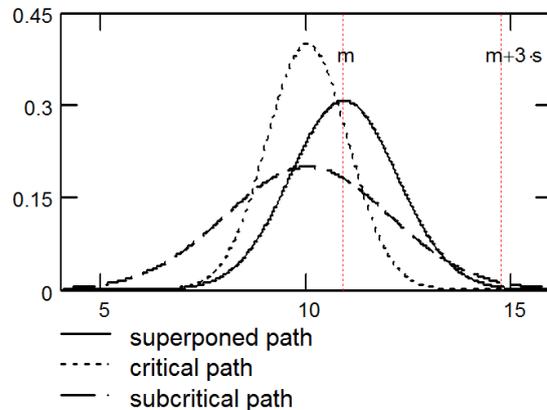


Figure 3. The distributions of probability of the critical, subcritical and superponed time flow

The results of the numeric simulation of  $n=10^5$  replications for the chosen characteristics:  $N[\mu_1 = 10, \sigma_1 = 1]$ , that is  $N[\mu_2 = 10, \sigma_2 = 2]$  and the final result of simulation are presented in the form of the the simulated average value  $m_{1,2}$  and the standard dispersion  $s_{1,2}$ , which generates the new distribution  $N[m_{1,2}, s_{1,2}]$ , (Figure 3).

Here normal distributions are obtained with:

- Theoretical values by Clark's equations  $N[\mu_{1,2} = 10,892062; \sigma_{1,2} = 1,305459]$ ,

- Simulation values:  
 $N [m_{1,2} = 10,891189; s_{1,2} = 1,301344]$  and
- Here the differences between the theoretical and the simulation values are:

$$\Delta\mu_{1,2} = 8,73 \cdot 10^{-4} \quad \text{and} \quad \Delta\sigma_{1,2} = 4,115 \cdot 10^{-3}.$$

However, as this algorithm is simply defined by computer, the main point of the problem is now oriented to the domain of simulation. In other words, in one session of simulation of  $n = 10^5$  replications, the testing of only one chosen variant was performed here, where  $\mu_1 = \mu_2$  and  $\sigma_1 < \sigma_2$  of nine possible variants.

### 5.2 The application of Monte-Carlo method in solving the Clarks's flow model

The extension of Monte-Carlo method domain and the visualisation of its results can be done by using the frames [6]. In that sense the supposition (6) can be solved in up to the three variants in one simulation session:

$$\mu_1 \left\{ \begin{array}{c} < \\ = \\ < \end{array} \right\} \mu_2 \quad \text{and} \quad \sigma_1 < \sigma_2. \quad (9)$$

The number of frames depends on the complexity of the problem, i.e. the process which is being studied, so this integrated Monte-Carlo method - animation (through frames) has a significant role. It can be partially presented by a series of selected frames at work [8].

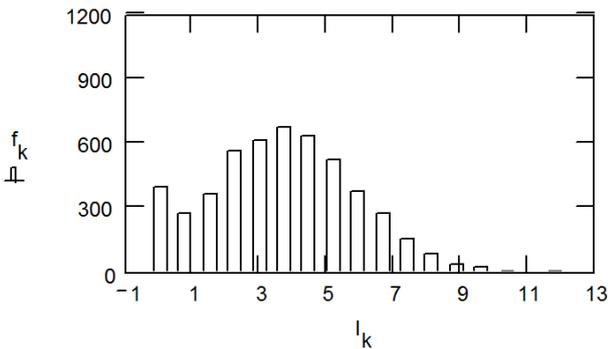


Figure 4. The value frame  $[\mu_1 = 14, \sigma_1 = 1]$

### 5.3 Some criteria for determining the equivalence of flows

When the number of the parallel independent (absence of correlation) flows is  $w \geq 2$ , then the criteria which are not completely universal can be developed, but they can be applied when the problem of superposition is solved analytically. Their definition can be applied in the next cases:

- ⊙ The condition of the equivalence of the two parallel flows is expressed on the basis of two parameters and three set relations (Figure 1):

$$\left( \mu_1 \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} \mu_2 \wedge \sigma_1 = \sigma_2 \right) \vee \left( \mu_1 = \mu_2 \wedge \sigma_1 \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} \sigma_2 \right) \quad (10)$$

$$\Rightarrow (\sigma_{1,2} \equiv \sigma_{2,1}) \wedge (\mu_{1,2} \equiv \mu_{2,1})$$

This criterion is based on the evidence of the invariability of the two flows  $\Pi_1$  and  $\Pi_2$ .

- Neither of  $w = 3$  parallel flows is equivalent in the next cases (Figure 4):

$$\left[ (\mu_1 \neq \mu_2 \neq \mu_3) \wedge \left( \sigma_1 \left\{ \begin{array}{c} = \\ \neq \end{array} \right\} \sigma_2 \left\{ \begin{array}{c} = \\ \neq \end{array} \right\} \sigma_3 \right) \right] \vee$$

$$\left[ (\mu_1 \left\{ \begin{array}{c} = \\ \neq \end{array} \right\} \mu_2 \left\{ \begin{array}{c} = \\ \neq \end{array} \right\} \mu_3) \wedge (\sigma_1 \neq \sigma_2 \neq \sigma_3) \right] \Rightarrow \quad (11)$$

$$(\sigma_{1,2} \neq \sigma_{1,3} \neq \sigma_{2,3}) \wedge (\mu_{1,2} \neq \mu_{1,3} \neq \mu_{2,3})$$

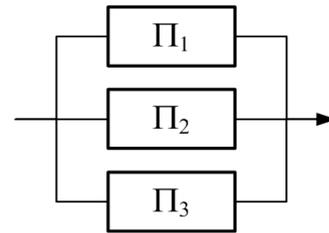


Figure 5. Subnetwork with three parallel flows of PDM structures with similar characteristics

The complete table of the relational operators for the three parallel flows with all the relational combinations of the expected values  $\mu_\nu$  ( $\nu = 1, 2, 3$ ) and adequate standard deviations  $\sigma_\nu$  is given in Table 2.

The number of combinations of the superposed flows  $u$  for the greater number of the elementary flows  $w$ , is of the exponential characters and is:

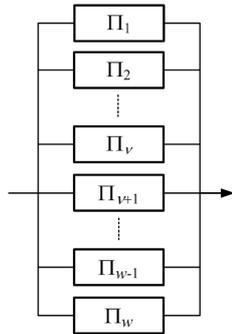
$$u = 3^{w+1} \quad \{w \geq 2, w \in N\}. \quad (12)$$

**Table 2. Combination of relations of the three expected values and three standard deviations**

$\mu_1 \rho \mu_2 \rho \mu_3$	$\sigma_1 \rho \sigma_2 \rho \sigma_3$	$\mu_1 \rho \mu_2 \rho \mu_3$	$\sigma_1 \rho \sigma_2 \rho \sigma_3$	$\mu_1 \rho \mu_2 \rho \mu_3$	$\sigma_1 \rho \sigma_2 \rho \sigma_3$
< <	< <	= <	< <	> <	< <
< <	< =	= <	< =	> <	< =
< <	< >	= <	< >	> <	< >
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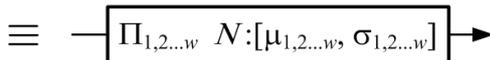
- The equivalence of the  $w$  - parallel flows is realized when the following conditions are fulfilled (Figure 5):

$$\begin{aligned}
 & \left[ \forall \mu_\nu = \mu_{\nu+1}, \nu = \overline{1, w-1} \right] \wedge \left[ \forall \sigma_\nu = \sigma_{\nu+1} \right] \\
 \Rightarrow & (\mu_{1,2...w} \equiv \mu_{2,1...w} \equiv \dots \equiv \mu_{w,w-1...1}) \wedge \quad (13) \\
 & (\sigma_{1,2...w} \equiv \sigma_{2,1...w} \equiv \dots \equiv \sigma_{w,w-1...1})
 \end{aligned}$$



**Figure 6. The subnetwork with  $w$  - parallel flows**

In that sense one can observe these flows as one equivalent flow with the characteristic:



**Figure 7. The subnetwork with one equivalent flow**

According to the previous criteria, only one case fulfills the condition of equivalence which is given in bold in the table 2. In the paper [5] it is shown how the equivalent superponed flows integrated with the ordinal flows are formed.

## 6. CONCLUSION

The most significant advantage of Monte-Carlo simulation method in solving this flow problem through the network is the possibility of modelling of the probability distribution function for the superponed flow time of the basic network model, given in figure 1. However, the advantage of Monte-Carlo simulation method is substantially increased on the account of possible dynamic modeling of the flow through the network. The frames made by scanning in the Mathcad provide more reliable basis for further acquiring and expanding of knowledge in this field, especially in relation to the relativity of the critical flow. We can perform the time planning of the critical flows with more credibility when using the combined procedures: analytical Clark's equations and numerical Monte-Carlo simulation than when achieving it by the standard procedures of network planning and managing, e.g. through PDM (Precedence Diagramming Method). With the classical PDM, the flow time planning is established on the expected values of the elementary flow times, which leads to a considerable mistake in planning, since the influence of the subcritical flows on forming the total superponed flow time is, in principle, neglected and super-positioned extracts  $\Delta\mu$  and  $\Delta\sigma$  are reduced to zero. It can be proved that, in the flow network with ten critical flows of the autonomous type, the resulting flow time increases by 11% from the time one should get when calculating by the PDM method. This "mistake in planning", as a theoretical result also verified by simulation for the two parallel flows, is  $\delta = 8,92\%$ . The result obtained in this way is not uniform, but it depends on the chosen value pairs of the numerous  $\Pi_\nu : [\mu_\nu, \sigma_\nu]$  ( $\nu = 1, 2, \dots, w$ ). Of course, it is possible to examine the remaining cases, too, through analytical and / or numerical methods, e.g. when we set the vector of the expected values and of the corresponding standard deviations in the next effect:

$$\mu_\nu \begin{Bmatrix} < \\ = \\ < \end{Bmatrix} \mu_{\nu+1} \text{ and } \sigma_\nu \begin{Bmatrix} < \\ = \\ < \end{Bmatrix} \sigma_{\nu+1} \text{ for } \nu = \overline{1, w-1} \quad (14)$$

These influences (Figure 6 and 7) can exceptionally be noticed [2], [8] by simulation at more complex ADM (PDM) networks. When the more complex flows are calculated (Figure 8), analytically or by simulation and respecting the developed criteria, one gets interesting values, because here the networks with both the ordinal and parallel flows are comprised. Example, for the initial information:

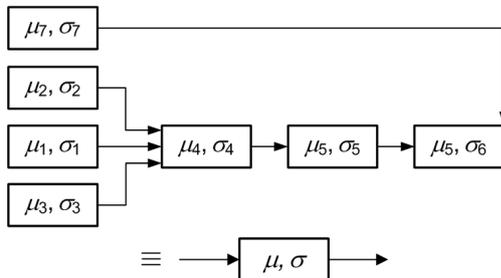
$$\mu_\nu = 100 \text{ and } \sigma_\nu = 10 \text{ for } \nu = 1, 2, \dots, 7.$$

- The analytical results are:

$$N [\mu = 413,4086; \sigma = 14,16232],$$

- The numerical results are:

$$N [m = 413,3794; s = 14,17712].$$



**Figure 8. The network with ordinally parallel flows and its equivalent**

The consequences of not knowing the essence of the obtained results can be very problematic, especially in the cases of planning and controlling the complex stochastic flows of activities through the network. Clark's equations for four and more parallel flows were not developed. If they were performed, they would lead to the very complex equations. However, the existing equations for two or three parallel flows can be used for solving even the more complex cases of flows ( $w \geq 3$ ). Then they are used as recurrent. For  $w^{th}$  iteration, the superposing of the flow  $\Pi_{12\dots w-1}$  and  $\Pi_w$  into the flow  $\Pi_{12\dots w-1,w}$  gives the following results:

- The expected superponed flow time  $\overline{T_{12\dots w-1,w}}$  is:

$$\overline{T_{12\dots w-1,w}} = \overline{T_{12\dots w-1}} \cdot \Phi(\xi_{12\dots w-1,w}) + \overline{T_w} \cdot \Phi(-\xi_{12\dots w-1,w}) + \lambda_{12\dots w-1,w} \cdot \varphi(\xi_{12\dots w-1,w}) \quad (15)$$

- The superponed dispersion  $\sigma_{12\dots w-1,w}^2$  is:

$$\sigma_{12\dots w-1,w}^2 = (\overline{T_{12\dots w-1}}^2 + \sigma_{12\dots w-1}^2) \cdot \Phi(\xi_{12\dots w-1,w}) + (\overline{T_w}^2 + \sigma_w^2) \cdot \Phi(-\xi_{12\dots w-1,w}) + (\overline{T_{12\dots w-1}} + \overline{T_w}) \cdot \lambda_{12\dots w-1,w} \cdot \Phi(\xi_{12\dots w-1,w}) - \overline{T_{12\dots w-1,w}}^2$$

Note: The underlined values are the expected or the average values of the arguments.

Because of the presences as well as of the ordinal flows, the mathematical and simulation models should be completed with the results of the *central limit theorem* [7].

More importance of the research results are:

- Provided a new approach to studying the impact of parallel flows in the resulting production flow.
- Introduced a superponed flow, and defines his time and variance, which are the basic parameters for sizing the intralogistic's capacity.
- Very credible be determined the time of the schedule implementation during process.
- Created the basis for measuring risk that a particular course will not be realized within the planned time.
- The significance of the relativity of the critical and subcritical flow.

The directions of further researches can be added.

- The solving of the Clark's more complex model when two parallel activities are correlated.
- The development of Clark's analytical model with three or more parallel flows into one equivalently-superponed flow.

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# GENETIC ALGORITHM APPROACH FOR SOLVING TRUCK SCHEDULING PROBLEM WITH TIME ROBUSTNESS

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***Abstract:** Problem considered in this paper regards inbound truck to dock door assignments in a cross-dock terminals with temporal constraints included in decision process. Because of stochastic nature of terminal related activities, modifications of already established operational plans are relatively frequent. These disturbances are mainly induced by inaccurate assessment of inbound trucks' arriving times, caused by unpredictable traffic conditions, as well as by stochastic nature of unloading operation within a terminal. We present a new approach for solving this type of problem by utilizing genetic algorithm framework. Eventually, we compare efficiency of presented algorithm with the algorithms already used for solving the problem.*

***Keywords:** cross-dock, operational planning, genetic algorithm.*

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## 1. INTRODUCTION

Cross-dock is a term used in logistics practice to refer to a process implemented mainly in hub terminals. Generally, cross-dock implies unloading of incoming transportation means at inbound doors, and loading of outbound trucks or trailers at outbound doors, with little or no storage in between. More precisely, general framework of a cross-dock terminal implies that after incoming trucks arrive at the inbound doors of the terminal, each arrived item is sorted in accordance with its destination and moved onto the shipping door where outgoing truck waits for making delivery to the designated destination. The movements of items from the inbound to the outbound doors are usually made either by fork-lift trucks or conveyors. Efficiency of this type of terminals is dependent on the quality of numerous cross-docks' strategic, tactical and operational problems.

Solving a strategic, tactical or operational problem implies making a decision, which, on the other hand is formalized by generating a plan. Based on that plan a problem is solved.

Accordingly, operational decisions result in operational plans which contain detailed information about realization of considered activities. Numerous operational decisions that have to be made in a

cross-dock terminal imply generation of numerous operational plans. One of those decisions is considered in this paper.

Despite the relatively precise information on which operational plans are made, because of stochastic nature of terminal related activities, modifications of already established operational plans are relatively frequent. These disturbances are mainly induced by inaccurate assessment of inbound trucks' arriving times, caused by unpredictable traffic conditions, as well as by stochastic nature of unloading operation within a terminal. High intensity of transshipment processes within a cross-dock terminal implies that any deviation from original operational plans has multiplicative impact of system performances by influencing all activities after the disorder point.

Because it is practically impossible to influence on traffic conditions in order to reduce truck arrival time inaccuracies, and because stochastic nature of unloading activities is practically inevitable, the best way to reduce operational plan disturbances is generation of robust operational plans. Such plans are capable of absorbing some level of variations in arrival and unloading truck times.

In this paper we present new metaheuristic approach of generating robust operational plans for one problem in serving inbound trucks in cross-dock terminals. After that we compare effectiveness and

efficiency of two variations of presented metaheuristic approach, and compare them to approaches and metaheuristic algorithms already presented in the literature. Based on the results of the computational experiments it is obvious that the main contribution of this paper is formalization of a solution methodology, based on the genetic algorithm framework. This algorithm provides solutions of large scale size problems in practically applicable times and with reasonable quality.

The rest of the paper is organized in such way that in the following section we give the problem description and brief literature review; in section three we present new metaheuristic approach for solving the problem; in section four we compare proposed solution procedures to existing solution procedures. Finally, in section five we give conclusion on obtained results.

## 2. PROBLEM DESCRIPTION AND LITERATURE REVIEW

Problem considered in this paper regards inbound truck to dock door assignments in a cross-dock terminals with temporal constraints included in decision process. This problem is known in literature as the truck scheduling problem (TSchP). The problem very similar to the TSchP is the dock assignment problem (DAP). Because of the similarity, the DAP is commonly misplaced with the TSchP. The main difference between these two problems is that DAP is considered only when set of inbound trucks is to be allocated on a set of available dock doors in such way that not more than one truck is assigned to each dock. The reason for such allocation is that DAP does not consider time as a constraint.

On the other hand, the TSchP considers time aspect of the problem and consequentially it allocates more than one truck on a dock door. In other words, TSchP considers the dock doors as resources (used by the trucks) that have to be scheduled over time. The problem decides on the succession of inbound trucks at the dock doors of a cross-dock: where and when the trucks should be processed [1].

More precisely, operational plan obtained by solving TSchP determines which trucks will be served on which dock door, as well as order of service for trucks served at the same door.

Because of its importance on effective realization of cross-dock operations, the TSchP has been subject of numerous research papers. As a result of problem complexity different cross-dock structures are considered in the literature, all with intention to

get insight into the problem by reducing the size of a problem. Some authors decided to consider only inbound or outbound parts of a cross-dock terminal, while others reduced a number of available dock doors in a terminal. For the reader interested in comprehensive literature review regarding the TSchP we recommend papers [1] and [2].

Another differentiate feature of the TSchP models is observed objective function. By classification used in [2] authors presented six the most widely used objective functions and leave place for some surrogate goals of a model.

Objective function considered in this research is firstly used by Acar in [3] and by Acar et al. in [4] with the goal to increase the robustness of the inbound truck schedule in a cross-dock to deviations in arrival times and unloading times. Therefore in the rest of the paper we refer to the problem as the TSchP with Time Robustness (TSchPTR). Aforementioned goal has been accomplished by using objective function that aims at spreading the slack time (time that remains after subtracting inbound trucks' service times from the time available for service at a dock door) as evenly as possible in order to create buffers to absorb variability in scheduled arrival and service times. This is achieved by minimizing the square of the slack time since this is equivalent to minimizing the variance.

Therefore if by  $N$  we denote cardinality of set of incoming trucks to be served on  $M$  available dock doors, and if  $S_{j,k}$  denotes idle time before task  $j$  served on dock door  $k$ , then objective function used in TSchPTR can be written as (1).

$$\min \sum_{k=1}^M \sum_{j=1}^{N+M} S_{j,k}^2 \quad (1)$$

It should be noted that values of index  $j$  larger than  $N$  refer to idle times after the last trucks served at a dock door, as well as that values of  $S_{j,k}$  are equal to zero for all trucks  $j$  not served at dock door  $k$ .

In [3] and [4] authors define mathematical model for obtaining optimal solution of the problem. The model consists of linear constraints, quadratic objective function and mixed, binary and continuous, variables. Because of combinatorial complexity of the problem, presented MIQP (mixed integer quadratic programming problem) can be useful only for small size problem instances. For large size problem instances authors presented the Door Assignment Heuristics (DAH). In [4] authors tested efficiency of the DAH in different dock utilization rates which showed that average deviation of DAH result from optimal ones were

around 9% in the case of high dock utilization, and around 4.5% in low utilized systems.

Metaheuristic approach in solving TSchP is not new. So far one can find several papers that already used it, and for example authors in [5] used it for solving complex case of the TSchP. However, the first metaheuristic approach for solving TSchPTR can be found in [6] where authors presented algorithm based on the Variable Neighborhood Search (VNS) metaheuristic framework. Tests conducted in the research showed that the VNS algorithm outperformed the DAH in terms of the objective function values. Nevertheless, VNS's running times seemed to increase exponentially with the growth of problem size. Therefore, in this research we present another metaheuristic algorithm whose running time increases at significantly lower rate, but which gives solution of satisfying quality.

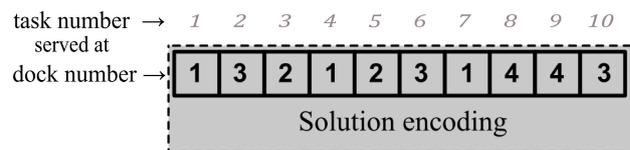
For a detailed insight into the mathematical formulation of the TSchPTR, the DAH, the Insertion and the VNS algorithm, the reader is referred to [4] and [6].

### 3. GENETIC ALGORITHM

Genetic algorithm (GA) is well known and widely used metaheuristic framework designed for solving different combinatorial optimization problems. The GA exploits of the main principles of the evolution of living organisms which eventually results in survival and future development of the best individuals in a population. Accordingly, realization of every GA consists of the following procedures: generation of initial population of problem solutions (aka chromosomes), selection of chromosomes for reproduction process, and reproduction process itself. Reproduction process is made of crossover, and mutation procedures. Procedures of chromosome selection and reproduction are repeated as long as one of algorithm's termination criteria is not fulfilled. During the algorithm's run initial solutions are successively improved toward a solution which is relatively close to the optimal solution of a problem. Closer insight to the GA's procedures used for solving the TSchPTR is the subject of this chapter.

One of the main characteristics of the GA is a solution encoding. Encoding used in this research is a consequence of the problem's nature. Namely, because the goal of the problem is to optimally distribute slack times between successive tasks on a dock, an optimal solution has to have increasing order of tasks on each dock in terms of truck incoming times. Therefore, in a problem of  $n$  truck arrivals that are to be served on  $m$  docks, solution

encoding is an array of  $n$  positions. Each position is related to the task whose ordinal number is equal to the position in the array, starting from the left hand side of the array, and it contains an information about the dock on which task is served. Size of the so encoded solution space is equal to  $n^m$ . For example, in problem with 10 tasks and 4 docks, the solution in which tasks 1, 4, and 7 are served on dock 1, tasks 3 and 5 on dock 2, tasks 2, 6, and 10 on dock 3, and tasks 8 and 9 on dock 4, is represented as 1,3,2,1,2,3,1,4,4,3. Illustration of this example is given on Figure 1.



**Figure 1. Solution encoding used in the research**

Each chromosome in the initial population of chromosomes is generated in a random manner.

Selection of chromosomes for reproduction process is realized by roulette wheel procedure. Probability for selecting a chromosome is obtained by implementing fitness function  $\phi(x)$  on value of chromosomes objective function  $x$ . Expression used for fitness function is given by (2),

$$\phi(x) = \frac{e^{f(x)-\mu/5}}{1 + e^{f(x)-\mu/5}} \quad (2)$$

where  $\mu$  represents average value of population objective function.

Chromosome pairs for crossover procedure are selected randomly with consideration that two same chromosomes cannot be selected. In such case one chromosome is replaced with some other chromosome from selected population. Eventually, if there are no two different chromosomes in a remaining crossover population, one of them is replaced with randomly generated one, as in initial population.

As crossover operators we used two simple but widely used ones. The first one is 1-point crossover operator where one break point on both parents is randomly selected. The first offspring is generated by combining the part before the break point on the first parent and the part after the break point on the second parent. The second offspring is generated accordingly, but with parents' counterparts. Illustrative example of the used 1-point crossover is presented on Figure 2.

The second crossover operator is 2-point crossover. This operator implies selection of two randomly selected break points for both parents. The

first offspring is generated by replacing first parent's part of chromosome between breaking points by second parent's part of chromosome between break points. The second offspring is generated accordingly but with reverse positions of parents. Illustrative example of 2-point crossover is presented on Figure 3.

		break point									
<i>Parent 1</i>	<b>1</b>	<b>3</b>	<b>2</b>	<b>1</b>		<b>2</b>	<b>3</b>	<b>1</b>	<b>4</b>	<b>4</b>	<b>3</b>
<i>Parent 2</i>	<b>4</b>	<b>3</b>	<b>1</b>	<b>1</b>		<b>2</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>4</b>
<i>Offspring 1</i>	<b>1</b>	<b>3</b>	<b>2</b>	<b>1</b>		<b>2</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>4</b>
<i>Offspring 2</i>	<b>4</b>	<b>3</b>	<b>1</b>	<b>1</b>		<b>2</b>	<b>3</b>	<b>1</b>	<b>4</b>	<b>4</b>	<b>3</b>

**Figure 2. An example of one point crossover used in the GA algorithm**

		break point 1				break point 2						
<i>Parent 1</i>	<b>1</b>	<b>3</b>		<b>2</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>1</b>		<b>4</b>	<b>4</b>	<b>3</b>
<i>Parent 2</i>	<b>4</b>	<b>3</b>		<b>1</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>2</b>		<b>3</b>	<b>2</b>	<b>4</b>
<i>Offspring 1</i>	<b>1</b>	<b>3</b>		<b>1</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>2</b>		<b>4</b>	<b>4</b>	<b>3</b>
<i>Offspring 2</i>	<b>4</b>	<b>3</b>		<b>2</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>1</b>		<b>3</b>	<b>2</b>	<b>4</b>

**Figure 3. An example of two point crossover used in the GA algorithm**

Mutation of the chromosomes is realized by selecting a random position in the array and changing its original value with a randomly selected value from a set of remaining docks.

#### 4. COMPUTATIONAL EXPERIMENTS

In order to test this algorithm's effectiveness and efficiency for solving the TSchPRT we exploit the set of problem instances used in [6]. Three sets of problem instances are considered, each with different problem complexity. The first set consists of 10 trucks (small problem size), the second of 25 (medium problem size), and the third of 50 (large problem size) trucks. Each truck has randomly generated arrival time according to uniform distribution on the [0, 8] h interval, as well as randomly generated duration of service time uniformly distributed on the [0.4, 2.4] h interval. It is supposed that service time of a truck is the same for all docks. The number of available docks changes with the number of trucks in the planning horizon. Accordingly, there are four, six and ten available

dock doors for the small, medium and large problem instances, respectively.

We observed planning horizon of 16 hours during which all, except first four docks, are available for service during [0, 16] h interval. The first dock is supposed to be available during [12, 16] h interval, the second during [8, 12] h interval, the third during [9, 16] h interval, and the fourth during [4, 14] h interval. Notice that first four docks are always used in serving trucks, regardless of problem size. Additional docks are used with the problem size increase according to the previously explained strategy.

Algorithm's termination criteria implied that search procedure is finished if after 100 steps there were not solution improvement. In every step we considered population of 100 solutions. Besides that, we supposed that probability of mutation is 0.1, and of crossover it is 0.95.

Because of the problem complexity only small size problem instances are solved to the optimality by using CPLEX 12.2's quadratic optimizer. In the cases of deterministic heuristics (DAH and Insertion) every instance is solved once, while in the cases of the VNS and GA every instance is solved ten times. All of the test runs were executed on a Windows XP OS powered by an AMD Phenom II 2.61 GHz processor with 1GB of RAM, while all of the coding was done in Python 2.5.

Results of conducted tests are summarized in Table 1 and Table 2. First three columns describe instances, precisely, ordinal number of an instance, number of inbound trucks to be allocated, and number of available dock doors. Column "Opt" in table 1 contain data about the objective value obtained for an instance by implementing CPLEX's quadratic optimizer. Column "DAH" contains data about the minimal objective function of an instance obtained by implementing DAH algorithm, proposed by Acer in [3]. Column "Insertion" in table 1 contain information on the minimal values of objective function for an instance obtained by implementing insertion algorithm, presented in [6]. Similarly, column "VNS" contains best out of ten solution objective values of implemented VNS algorithm, proposed also in [6]. Columns, "GA - 1opt" and "GA - 2opt" contain data about the best objective values related to the implementation of GA based algorithms presented in this paper.

Table 2 holds information on average time an algorithm requires for an execution. First three columns in table 2 have the same meaning as in the case of the table 1. Following six columns refer to the same algorithms, but now containing data about

the average time required for obtaining a solution of the TschPTR.

**Table 1. Minimal values out of ten obtained solutions**

Inst	N <sup>o</sup> of trucks	N <sup>o</sup> of docks	Opt	DAH	Insertion	VNS	GA 1point	GA 2point
1	10	4	7.33	20.54	8.05	7.33	7.33	7.33
2	10	4	7.44	21.57	8.38	7.44	7.44	7.44
3	10	4	8.38	23.35	8.53	8.38	8.38	8.38
4	10	4	5.65	20.29	6.04	5.65	5.65	5.66
5	10	4	6.52	20.28	6.88	6.52	6.54	6.53
6	10	4	8.12	21.25	8.41	8.12	8.12	8.12
7	10	4	8.49	24.16	9.93	8.49	8.49	8.50
8	10	4	9.62	23.19	10.19	9.62	9.62	9.62
9	10	4	11.52	25.22	11.99	11.52	11.53	11.52
10	10	4	5.30	18.17	5.32	5.30	5.30	5.30
11	25	6		39.34	20.58	19.84	19.88	19.86
12	25	6		43.23	21.91	20.65	20.66	20.68
13	25	6		30.62	17.23	17.07	17.12	17.11
14	25	6		43.52	23.03	22.14	22.17	22.18
15	25	6		28.47	14.85	13.82	13.84	13.86
16	25	6		32.93	18.86	18.27	18.30	18.28
17	25	6		39.58	20.16	19.21	19.26	19.21
18	25	6		36.22	18.39	17.21	17.27	17.25
19	25	6		37.42	16.31	14.94	14.95	14.96
20	25	6		45.17	22.97	22.31	22.33	22.33
21	50	10		59.29	43.61	43.01	43.11	43.22
22	50	10		57.30	43.54	42.14	42.54	42.53
23	50	10		59.50	46.26	45.20	45.40	45.40
24	50	10		138.11	137.89	54.81	58.13	58.24
25	50	10		246.68	235.54	54.43	60.78	60.96
26	50	10		187.09	189.18	42.19	45.05	43.68
27	50	10		161.19	156.36	44.05	44.61	45.17
28	50	10		166.37	165.88	45.86	49.89	49.73
29	50	10		161.24	155.01	50.93	55.19	53.87
30	50	10		148.88	142.15	45.03	53.71	54.16

On the other side, time robustness of the GA caused decrease in the solution quality, compared to the VNS. Precisely, while the differences in solutions' objective values in the case of small and medium problem instances are negligible, they significantly increased in the case of the large problem instances.

**Table 2. Average algorithm run time in seconds**

Inst	N <sup>o</sup> of trucks	N <sup>o</sup> of docks	Opt	DAH	Insertion	VNS	GA 1point	GA 2point
1	10	4	2426.2	<0.01	<0.1	0.30	1.37	1.35
2	10	4	3161.3	<0.01	<0.1	0.27	1.17	1.10
3	10	4	2719.4	<0.01	<0.1	0.26	0.97	1.12
4	10	4	2804.2	<0.01	<0.1	0.26	1.14	1.29
5	10	4	1867.7	<0.01	<0.1	0.23	1.34	1.08
6	10	4	2191.5	<0.01	<0.1	0.26	1.04	1.09
7	10	4	4441.9	<0.01	<0.1	0.29	1.27	1.12
8	10	4	2840.0	<0.01	<0.1	0.31	0.93	0.96
9	10	4	3241.1	<0.01	<0.1	0.35	0.98	1.13
10	10	4	2914.8	<0.01	<0.1	0.25	1.37	1.12
11	25	6		<0.01	<0.1	9.82	1.80	2.16
12	25	6		<0.01	<0.1	9.12	2.48	2.15
13	25	6		<0.01	<0.1	9.08	2.44	2.07
14	25	6		<0.01	<0.1	10.89	2.47	2.87
15	25	6		<0.01	<0.1	9.90	2.16	2.07
16	25	6		<0.01	<0.1	8.73	2.57	2.49
17	25	6		<0.01	<0.1	10.50	1.77	2.07
18	25	6		<0.01	<0.1	10.22	2.76	2.28
19	25	6		<0.01	<0.1	11.58	2.39	2.45
20	25	6		<0.01	<0.1	11.36	2.35	2.32
21	50	10		<0.01	<0.1	221.14	5.55	6.70
22	50	10		<0.01	<0.1	300.09	7.55	8.07
23	50	10		<0.01	<0.1	236.69	6.91	7.18
24	50	10		<0.01	<0.1	224.78	10.17	9.08
25	50	10		<0.01	<0.1	313.02	11.43	10.17
26	50	10		<0.01	<0.1	223.79	11.81	9.70
27	50	10		<0.01	<0.1	200.45	9.06	8.98
28	50	10		<0.01	<0.1	215.51	12.14	8.75
29	50	10		<0.01	<0.1	246.69	9.08	8.81
30	50	10		<0.01	<0.1	266.70	12.85	10.25

Therefore, based on obtained results it can be concluded that implemented encoding may be very useful for solving large instances of the TSchPTR. However, in order to improve solution quality of large instances an effort has to be made in direction of finding more appropriate crossover operators. Accordingly, the following research related to the TSchPTR will be pointed in that direction.

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# OPTIMISATION OF THE PORT OPERATION SYSTEM WITHIN DP WORLD AUSTRALIA

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**Abstract:** The paper summarises DP World’s experience in optimisation of container terminal activities on a network of container terminals in Australia by creating a single operating interface across all four DP World terminals in Australia. A single operating centre, as demonstrated by DP World in Australia, provides more efficient container terminal operations and standard service with reduced cost and increased efficiency of the overall logistic chain under a corporate environment. The paper also presents DP World Australia’s standardisation and optimisation of terminal users’ requests process that provides logistic users’ in addition of tracking of container flow, but also monitoring and tracking of a progress of their service requests related to container flow.

**Keywords:** optimisation, container terminal DP World.

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## 1. INTRODUCTION

Seaports are complex and dynamic entities, often dissimilar from each other, where various activities are carried out by and for the account of different actors and organisations. Such a multifaceted situation has led to a variety of operational, organisational and strategic management approaches to port systems [1].

DP World (DPW) has a portfolio of more than 65 marine terminals across six continents. Container handling is the company’s core business and generates around 80% of its revenue. In 2012, DP World handled more than 56 million TEU (twenty-foot equivalent container units). With its committed pipeline of developments and expansions, capacity is expected to rise to more than 100 million TEU by 2020, in line with market demand.

DP World Australia manages a network of four container terminals in Australia including Brisbane, Sydney, Fremantle and Australia’s busiest and largest container terminal in the Port of Melbourne (Figure 1).

The Port of Brisbane is the third largest capital city port in Australia. DP World’s Fisherman Islands Terminal (FIT) is located at the mouth of the Brisbane River, 17 kms downstream from the city of Brisbane. FIT represents one of the most modern deepwater terminals on the Australian coast and features a 900 metre wharf serviced by four quay Post-Panamax cranes, - designed for the new generation of container vessels. FIT is currently

undergoing expansion and change of mode: from forklift / reach stacker to semi automated ASC operations. By the end of the year the facility area will grow to 36ha and capacity in excess of 900,000 TEUs.



**Figure 1. Locations of DP World’s container terminals in Australia**

Fremantle is the principal port of Western Australia, situated at the mouth of the Swan River on the western coast of Australia. It has easy rail and road connections to the other major Western Australian centres and other states. Located within the Port of Fremantle’s inner harbour, Fremantle Terminal is equipped with specialised container handling equipment and computerised control systems and has extensive reefer facilities.

The Port of Melbourne is located at the mouth of the River Yarra, at the head of Port Phillip Bay and

adjacent to the city of Melbourne, the capital of the state of Victoria. Melbourne is the largest container handling port in Australia.

DP World Melbourne West Swanson Terminal opened in 1969 and was completely redesigned and redeveloped in 1995 into a full straddle operated terminal. It is equipped with the latest terminal control system and has easy access to rail facilities at the nearby Dynon rail terminals and the adjacent Intermodal site.

The DP World Sydney Container Terminal is strategically located in a protected harbour, on the northern shore of Botany Bay, 12 nautical miles south of Sydney Harbour. The terminal is located within the state's significant Sydney Airport/Port Botany precinct. The Port Botany terminal is DP World's second largest container terminal in the Australia – New Zealand (ANZ) region. The facility also boasts the latest in container handling equipment, a fully integrated computerised control system along with extensive reefer plug-in and monitoring facilities.

Container terminal operators are important facilitators of international trade. They help to bring out the potential competitive and comparative advantages of their hinterland. Although terminal handling charges play an important role in influencing the attractiveness of a container terminal, its users are ultimately concerned with the overall costs associated with using the terminal [2]. Container terminals that offer the most sustainable value to its users at the most competitive cost against other container terminals in other competing systems would be chosen as the terminal-of-call [3].

One of the ways to improve port efficiency, usually analysed in literature is to fully automate its container yards. In so doing, they could possibly improve operational efficiency by eliminating the inefficiency of humans. As a result, significant cost saving can be achieved by improving the productivity of the container terminal and reducing labour cost [4]. Other than carrying out port automation, one possible way is through optimisation. Basically, an optimised port operation system is able to maximise the utilisation of port facilities and provide a cheaper solution to achieve better port efficiency [4].

DP World's approach to the port operation system optimization is based on centralization and creation a single operating interface across all of the container terminals in the region, and through standardisation and optimisation of Customer's Special Service Request Process, providing an enhanced and innovative service to their clients.

Introducing above mentioned port operation optimization concepts and presenting their characteristics is the main objective of this paper.

The paper is organized as follows. Section 2 presents the centralisation concept, while Section 3 describes elements of the Special Service Request Process. Some concluding remarks are given in Section 4.

## **2. DP WORLD'S CONCEPT OF THE PORT OPERATION CENTRALISATION**

DP World in ANZ is in the unique position of supplying terminal services to Shipping Lines through exclusive nationwide contracts. Thus DP World stevedores the vessels of a particular service in all of the ports they call in Australia. This has given DP World the opportunity to create a single operating interface across all of the container terminals in the region providing an enhanced and innovative service to their clients.

In this way the need for reconceptualisation of the conventional port as a fixed and spatial entity to a network of terminal operating firms under a corporate logic [5], has become operational.

The move was successful which is confirmed by our main competitors adopting a similar model and have created similar centres within their organizations.

The centralisation and optimisation concept rests on Vessel Operations Group (VOG) and National Planning Centre (NPC).

The DPW Vessel Operations Group provides centralised and automated Customer Management, Coastal Scheduling and Vessel Planning services. It is the operational interface that coordinates and manages the flow of information between our customers and our business. VOG control and monitor client vessel's coastal arrivals and movements through the National Vessel Coordinator, and also it is an entry point for clients' planning offices and provides terminal planning services to DP World terminals in Australia.

National Planning Centre (NPC) as a planning and customer service branch of VOG provides:

- Ship exchange plans, (Order of Work; sequence sheets etc);
- Seaworthiness of planned vessels;
- Effective solutions to vessel operations, minimum cost; adequate utilisation of terminal resources and vessel space;
- Shipment of exceptional cargoes: Hazardous (HAZD), Break-bulk (BBLK), Out of Gauge (OOG) etc;

- **Container Data Management**

In 2012 the Vessel Operations Group coordinated 125 different vessels making total of over 2246 port calls in Australia and plan and sequence nearly 2.3 million container moves for all 4 DPW terminals in Australia.

This equates to 225 port calls and 230,000 container moves per planner annually.

As a comparison in 2002 the last year of terminal based planning, the annual equivalent was 99 Port calls and 62,000 moves per planner.

The value of a single point entry to the external client is that one telephone number is all that is needed for both planning and scheduling services which will reach someone that will be able to help them 24 hours a day 365 days a year for any DP World terminal in Australia. Moreover the person they are dealing with will be familiar to them and accustomed to their specific needs.

Single point entry also has some important advantages to DP World:

- It enables DP World to closely manage their working and commercial relationships with their clients by tying together the planning and scheduling functions.
- It enables DP World to provide a strong customer focused service recognising individual client needs.
- It provides the opportunity to forge closer ties with clients by breaking down the traditional relationship barriers and replacing these with a common approach to operational issues.
- It provides DP World the opportunity to provide operational and technical feedback and assistance to shipping lines to enhance the operational interface.
- It enables DP World to rationalise communications recognising the changing structure of the global shipping industry.
- It enables DP World to create a culture of reliance and trust in their relationship with their clients by providing in depth operational assistance and support.
- The ability to combine schedule coordination and the planning function enables DP World to exert greater control over coastal movements reducing the impact of vessel arrival peaking during periods of congestion

A centralised planning centre has a number of benefits for our terminals:

- It provides a nucleus of highly experienced planning staff who have a clear appreciation of terminal requirements and operational limitations around the coast.
- It provides a cost effective 24-hour service that would be onerous to replicate at the terminal level.
- Planners are focused on providing a high quality product for both Shipping Line and Terminal. This leads to a better working understanding at all levels of the relationship.
- Planners and vessel's staff develop a better relationship due to the frequency of contact. This allows ship board problems to be resolved professionally and quickly reducing potential operational delays at the terminal.

DPW NPC is working in a very vibrant environment that has very different needs, practices and standards: 4 different terminal working practices; 4 different yard planning strategies; multiple traffic flows and stack access; 25 vessel operators, 29 planning centres and 30 different shipping lines offices; 21 different trades, more than 120 different vessels on regular services; 37 – 40 vessels per week,

At the beginning NPC adopted local practices and processes related to ship planning and vessel operations with minimum intentions to make changes to, at that time, already established local vessel operations (except changes due to centralised non terminal based planning function). However during years NPC has developed into one of the driving forces for standardisation and optimisation of vessel operations and customer service in all 4 terminals on national level.

### **3. STANDARDISATION AND OPTIMISATION OF CUSTOMER'S SPECIAL SERVICE REQUEST PROCESS**

#### **3.1. The main idea and the concept**

Special Service Requests (SSRs) relate to the update or change to container records such as change of Port of Discharge, change of vessel / voyage, change of ISO code, change of Final Destination, change of container Export Document Number (EDN) / Custom Authorisation Number (CAN), change of reefer temperature or vent settings, change to commodity code etc as well as special activities such as: late receivals, container inspection, HAZD exemptions etc (Figure 2.).

DPW's clients use to send service requests via email to the NPC and /or to DPW terminals

requesting changes to container details or special services related to particular containers. This process was inefficient with lot of waste; the procedures within terminals were different which required additional training for DPW staff as well as for external clients. The main problems we were faced with were:

- External Clients: Service Failure (request not received, not actioned); Clients were not able to monitor the progress of the status of the request; Authorization of requests, acceptance of associated costs; Training due to Change of personnel
- Internal Clients (Terminals and NPC): Revenue leakage - service provided but billing event not captured; Invoice dispute – lack of documentation; Change of internal processes and responsibilities; Large number of emails; Service requests with insufficient data, chain emails; SSR Process Management, Priorities, Monitoring, Reporting and Training

DPW NPC has developed a web-based application that allows shipping lines to lodge Special Service Requests (SSR) through the DPW Customer Portal which has replaced the old system based on emails.

This new system is simple to use and provides a common workflow of service requests enabling the tracking of SSRs through automated notification and reporting. The new standardised processes have improved the response times to clients' requests and have substantially reduced the incidence of error.

Under the new system special service requests are lodged through the DPW Customer Portal (held at 1-Stop). Users are also able to send EDI messages for particular SSR using system to system connection as special arrangement (Figure 2).

User receives confirmation of lodgement and is provided with an SSR reference number after the request is submitted. This allows the User to monitor the progress of an SSR which will be automatically updated in the system as its status changes.

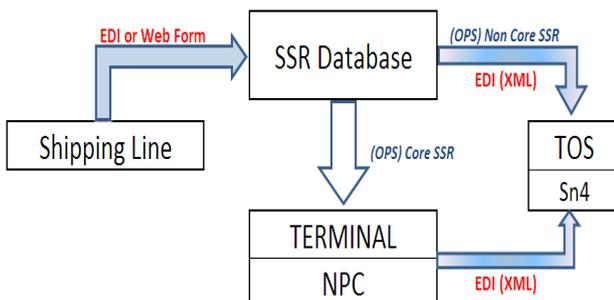


Figure 2. SSR System structure

The system provides the following benefits:

- 24/7 online request using DPWorld Portal
- Paperless work
- Standardised format which ensures that all necessary data and information has been supplied eliminating the need for clarifying correspondence
- Reduced response time
- Escalation methodology
- One point of contact
- Improvements in the billing
- Intimation of pending SSR request
- Reduction of revenue leakage - service provided but billing event not captured
- Reduction of invoice dispute
- Workflow management of internal processes and responsibilities
- Elimination of workflow process errors
- Transparency of the progress of the request
- Reduction of email traffic

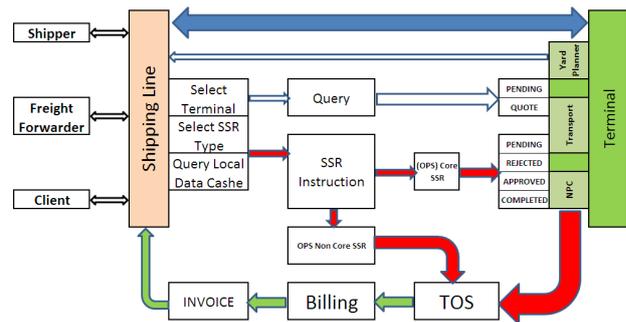


Figure 3. SSR workflow diagram

### 3.2. Web-based application for SSR

New system for Special service request is implemented through the web based application offering wide types of SSRs, which could be easily selected from the drop-down list. SSR workflow diagram is shown in the Figure 3. The SSR workflow has 4 sub-workflows:

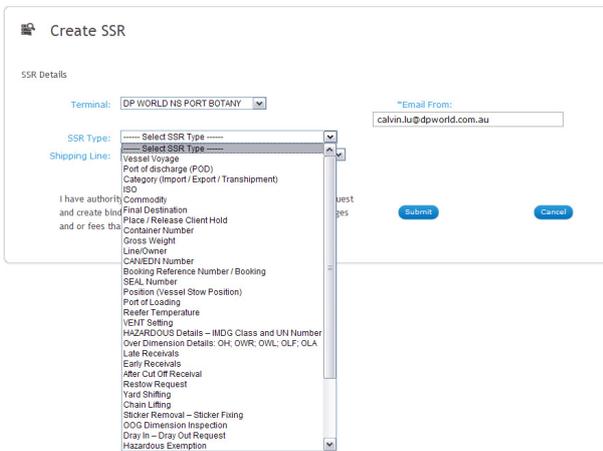
- Query workflow where client (shipping line) query cost and operational possibility for particular request; after assessment with 3<sup>rd</sup> party (shipper etc) a query might become a SSR request (instruction)
- SSR Instruction – request for terminal to action particular instruction;
- Billing and Invoicing of completed activities
- Email workflow between terminal and client–information of the status of particular SSR.

At terminal level workflow (email notification and SSR dashboard) are set as per adequate

operations procedures which ensures that all relevant users are correctly and timely notified of the request and activity they have to perform and to complete the SSR.

Shipping Lines' users control the notification workflow between them and their clients (shippers, freight forwarders, transport co etc) by adding relevant email addresses as recipients of SSR change of phase notifications (pending, approved / rejected, completed etc).

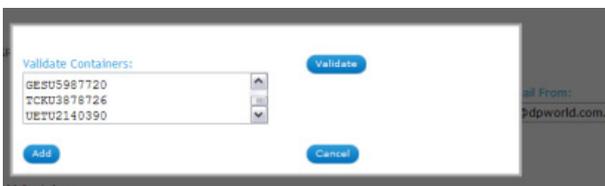
Software application assumes performing the following steps visually presented by a few screenshots of the users' interface. After successful login, the process of creation SSR begins with user's selection of the terminal and the type of SSR from the drop-down lists.



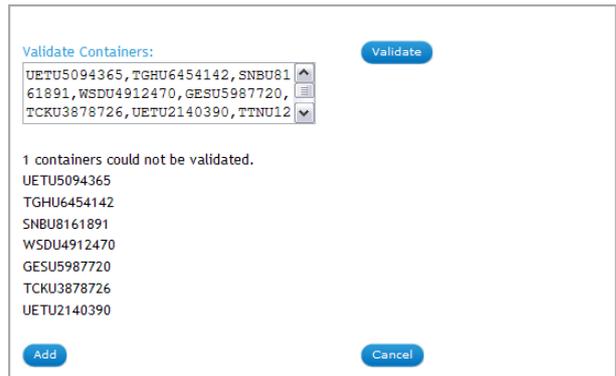
Then, user needs to "click" **Add Container** to add containers which are required for changes.



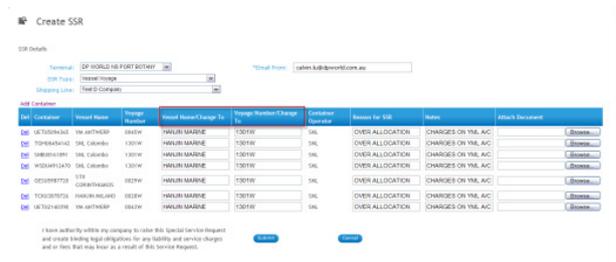
After containers are added they should be validated by "click" on **Validate**.



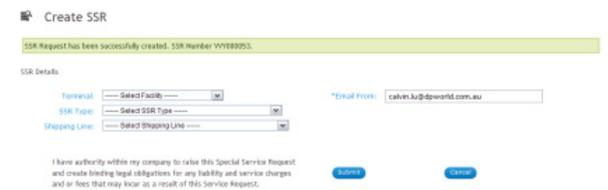
The system will validate the container numbers through terminal system and return the result. It will ONLY list all the validated container numbers.



Requested change is then typed in the **Change To field** and other optional fields like **reason** and **notes**, and then submitted by "clicking" the **Submit** button.



If successful, the screen will be displayed as below with ticket number generated automatically, and an email notification will be automatically sent to relative parties.



Some of the SSR types require documents to be attached, e.g. B959 form, Break-bulk photos etc. This can be inserted while creating the SSR. The attachment will be sent together with the notification via email.

User will receive an email confirming the SSR has been successfully submitted indicating the terminal, type of request, SSR Number and SSR details; with hyperlink to SSR Reporting or the Management Screen.



Additionally, system generates following mails: Acceptance and Completion of SSR.

Since all data related to SSR are saved in database, user can search SSR by Container number, terminal, SSR type and SSR status.

From the port managers and port officers' point of view, application offers opportunity for generating two types of reports, while Management screen is used for audit of particular SSR.

Container Report shows a list of detailed container numbers by SSR type and status set in the parameters panel.

Container No.	Terminal	Voyage No.	SSR Type	Status	Notes
YV98803	121002013	121002013	YV98803	Completed	Completed on 10.11.2013

The second report "SSR Report" shows a list of SSRs by type set in the parameters panel.

Terminal	Date From	Date To	SSR Type	Total Container Count
121002013	12/10/2013	12/10/2013	YV98803	1
121002013	12/10/2013	12/10/2013	YV98803	1
121002013	12/10/2013	12/10/2013	YV98803	1

#### 4. CONCLUSION

Optimisation of a network of terminals in a particular region by creating a single operating interface across all terminals, as demonstrated by DP World in Australia, can provide a more efficient and standardised service to container terminal users, while reducing the cost and increasing the efficiency of the overall logistic chain under a corporate environment. Increasing terminal efficiency, as continuous process, is not related only and exclusively to automatization of yard, waterside and landside operations. Terminal efficiency is also related to optimisation of terminal operations

activities on a network of terminals in a particular region such as vessel scheduling and ship planning, as currently in DPW ANZ region, but it can also be expanded to other operational activities. The productivity of ship planning team in DPW, for example, has increased nearly 4 times – from 62,000 to 230,000 moves per planner. Standardisation and optimisation of terminal users' requests is providing logistic users' with full control of container flow, not only by monitoring the progress of container moves into, within, and out of the terminal but also to monitor their service requests related to container flow. In the first month after Special Service Request implementation in DPW ANZ the service response time has been reduced by more than 15% .

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## SOME SAFETY ASPECTS OF PALLET RACKS

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**Abstract:** Warehousing as logistics function generates different specific activities. Related to this, some of these activities can be possible sources of different kinds of danger, depending on the type and quantity of inventories (goods), technologies, applied equipment, environment, human factors etc. In the palletized goods warehousing domain, selective pallet racks represent typical technology, which has been multiple confirmed and is widely spread. However, the racks themselves (although they are typically statically elements) might be the source of possible danger. Their cause might occur in the phases of their design, construction, exploitation and control. This set of influences and dangers has resulted with introduction of new specific regulations in some of these areas. Having that in mind, the aim of this paper is to point out to some analysis directions and preventive activities related to the safety of pallet racks.

**Keywords:** warehousing, pallet racks, safety, prevention.

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### 1. INTRODUCTION

Warehouse as a system is usually an essential part of any supply chain (SC). Warehousing activities generate a set of tasks, whose realization quality and performances directly or indirectly affect the efficiency of logistics processes in SC. Spectrum of warehouse's types, having in mind the role of warehouse, types of stored goods, size, throughput etc. is very wide. Within this spectrum, warehouses for palletized goods represent a significant group. Within warehouses for palletized goods, technologies based on selective pallet racks are „The oldest and still most popular type, selective pallet rack system utilizes horizontal beams connected to prefabricated upright frames to provide independent, multiple-level storage...“ [2]. The most common rack type [01] is adjustable pallet racking-type (APR)", accounting for approx. 80 % of the racking market [4].

Technological solution of APR warehouses is not one-dimensional problem – it depends on three basic subsystems [6]:

- stored goods
- equipment/elements used for warehouse processes and materials handling (MH) (dynamic, statically, personnel etc.)
- facility (building object) where warehouse processes are realized.

Each of those subsystems is described with set of relevant characteristics and they are essential for selection and implementation of some warehouse solution. During warehouse design, first of all, designer has to respect those subsystems and their relevant characteristics. For stored goods, the first is **unit load** (dimensions, shape, weight, ...), stored, received, processed and shipped quantities, as well as some present specific demands (sensitivity, combustibility and so on).

**Equipment/elements used for warehouse processes and materials handling (MH)** in APR, respecting different tasks, could be used in wide variety of technical-technological solutions, based on viable combinations of dynamic MH equipment and pallet racks. In this paper set of feasible technological combinations include counterbalanced and reach trucks forklifts and APR. It is obvious that during warehouse design techno-exploitation characteristics (for example, capacity, lifting height, turning radius, aisle width etc.) have to be respected. **Facility (building object)** with their characteristics has a great influence on technological solution of warehouse, at the first by setting criteria that limit the use of some types of equipment (statically or dynamically). Here, special treatment has to deal between clear height, (eventually) arrangement of construction elements (walls, columns, etc.), their quality (floor especially) and so on.

Each of mentioned subsystems itself, as well as their combinations, have influence on quality of

warehouse solution and quality of processes functioning. When the main objective of warehouse function is realized (based on productivity and efficiency), very important aspect is the safety of processes realization in the warehouse (WH) system. WH is the place where high quantities of goods are concentrated, typically with high frequently moving of dynamic MH equipment (with and without good) and personnel. Assuming that, there are potential hazards for humans, also for material recourses and the wider environment present. Those facts initiated the need that the area of racks and their use in the WH, with the technical and scientific aspect, have to be the point of interest of potential hazards. Sources of potential hazards may arise in the early stages of rack „life“ – during design of APR structure, then during structure elements manufacturing, installation, operation and control. Each of potential hazards (or their combinations) is important for APR safety aspect [4].

Having mentioned in mind, this paper consists of several parts: after introduction (this chapter), second chapter presents briefly presentation of APR components, construction, installation and overview of present regulations and recommendations. Third chapter discusses area of design and implementation of WH design solution. Special attention is given to prevention, use of regulation and/or good practice and manufacturer's recommendations, concerning on safety aspects. The fourth chapter is focused on aspects of safety in APR exploitation, which has set of components – from the proper pallet unit (PU) forming / control to the working conditions in the warehouse. The fifth chapter includes concluding remarks in these issues and potential direction for further activities and researches.

## 2. SELECTIVE PALLET RACKS - APR

APR is 3D steel/metal structure designed for PU storing. It consists of the basic components shown in Figure 1.

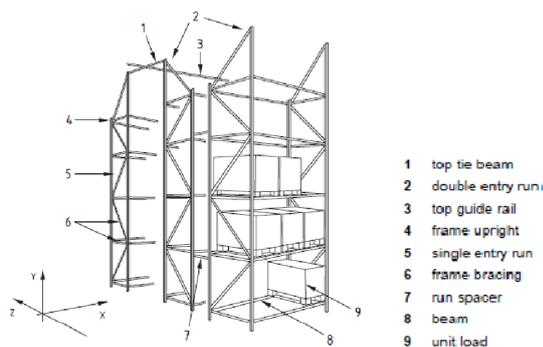


Figure 1. APR components (EN 15620)

APR is the system of upright frames connected by horizontal beams to provide pallet storage levels, which can be adjusted vertically. Each pallet storage position can be accessed individually. [7]

In the area of rack structure as well of its basic elements in practice there are a number of versions that differ in a number of characteristics – capacity, dimensions, type of metal profile etc. Rack elements have been and are now topic of wide researches – from profile manufacturers, equipment manufacturers, specialized institutions for quality control and so on. In mentioned scope few of associations are established and are present: in the USA – RMI (Rack Manufacturers Institute, established 1958); in Europe - FEM (European Federation of Materials Handling) Product Group "Racking & Shelving" was established in 1970 as Section X of FEM and today operates as the European Racking Federation (ERF). Their topics are structural design, layout and configuration design, project specification and safe use and recommendation and standards implementation (Table 1 and Table 2) [4].

Table 1. Review of standards in EN series "steel static storage systems"

First draft*	EN standard	Published
FEM 10. 2. 02	EN 15512: Adjustable pallet racking systems - Principles for structural design	March 2009
FEM 10. 3. 01	EN 15620: Adjustable pallet racking - Tolerances, deformations and clearances	October 2008
FEM 10. 2. 03	EN 15629: Specification of storage equipment	November 2008
FEM 10. 2. 04	EN 15635: Application and maintenance of storage equipment	November 2008
-	EN 15878: Terms and definitions	July 2010

\* The FEM codes with their commentaries are still available.

It could be concluded that in this field process of harmonization of regulations is present, aiming easier manufacturer's market share. In Serbia this field is "covered" with standards (SRPS EN 15635), which are compliant with relevant EN standards.

## 3. DESIGN AND DEVELOPMENT OF TECHNOLOGICAL WH SOLUTION BASED ON APR IMPLEMENTATION

In forming WH technological solutions as a primary emphasis on the following factors [13]:

- goods with their characteristics,
- technology of MH (Materials Handling)
- facility (building object)

Each of them during design process is present as request generator and/or limiting factor(s). Respecting purpose of this paper, below their briefly

presentation is made, according primarily on safety aspect.

**Table 2. Review of FEM codes of practice published, ongoing or planned**

FEM code	Title	Published**)
FEM 10.2.05 draft/ not published	Guidelines for working safely with lift trucks in pallet racking installations	October 1999 (final: ???)
FEM 10.2.06 provisional	The design of hand-loaded static steel shelving systems	April 2001
FEM 10.2.07	The design of drive-in and drive-through racking	September 2012
FEM 10.2.08	Recommendations for the design of static steel pallet racks under seismic conditions	May. 2011
FEM 10.2.09	The design of cantilever racking	(mid-2013)
FEM 10.2.10 (FEM 9.841*)	Storage systems with rail-dependent storage and retrieval equipment - Interfaces	February 2012
FEM 10.2.11 (FEM 9.842*)	Rail-dependent storage and retrieval systems - Consideration of kinetic energy action due to a faulty operation in cross-aisle direction, in compliance with EN 528 - Part 1: Pallet racking	(mid-2013)
FEM 10.3.01-1 (FEM 9.831-1*)	Basis of calculations for storage and retrieval machines - Tolerances, deformations and clearances in the storage system Part 1: General, single-deep and double-deep beam pallet racking	October 2012

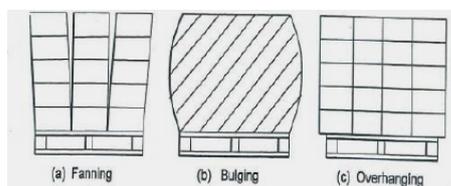
\* Drafted in liaison with the FEM Product Group "Intralogistic Systems"; their document numbering starts with "9".

\*\* Dates in brackets are target dates.

### 3.1 Goods

In this paper is assumed that good is presented as palletized unit (PU) - EURO pallet. Designer first of all has to have information about PU number, dimensions and weight. Having those information, he could closer define requests that are concerned on WH technological solution.

Also, the base assumption is that the goods on pallets is stacked in the manner that enables safe handling and that dimensions do not exceed the prescribed tolerances. Figure 2 presents few typical examples of PU dimensions larger than the pallet area and inappropriate goods secured on the pallet – when that PU can affect their placing.

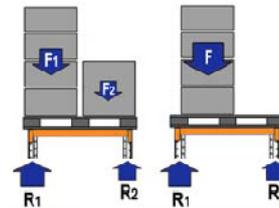


**Figure 2. PU that are not acceptable to APR [1]**

If such cases are present during WH design, it is necessary to involve appropriate interventions on PU and to respect obtained tolerances. This is very important to APR design, especially beam elements. For APR design also important could be probability distribution of PU height (aiming to define determinative beam height) and weight (to define

determinative capacity of vertical frames and the load carrying component) [8].

During design, in this domain could be present problem connected with non-uniformity of load stocking on the pallet (Figure 3). Then, this fact has to be respected during rack elements design. Non-uniform loads result in unequally loaded beams and uprights. A maximum of 10 % for both non-uniformity of load and asymmetrical placement is acceptable (06).



**Figure 3. Some examples of non-uniformity of load stocking on the pallet [9].**

### 3.2 MH Technologies

In a scope of technological solution of MH in WH, design includes two basic subsystems – pallet racks and forklifts. During design process designer has to define combinations of forklifts according their operating characteristics simultaneously with appropriate pallet rack structure (at first respecting forklift’s capacity and max. lifting height). Forklift (according type, construction, dimensions and pallet position on the forks) has direct influence on aisle width, which could differ on data presented in manufacturer’s technical documentation. Also, on growing aisle width can influence a intensity of material flow in WH: „In determining reasonable operating clearances, the density and speed of traffic in the warehouse must be considered. In a high throughput operation (a grocery or soft drinks distribution centre being typical), the operating clearances should be increased substantially“ [10].

ERF / FEM recommendations in this domain are presented in [03] (pages 35, 38 and 56). Also. during rack elements design it is necessary to respect adequate clearances between PU and APR structure elements, as a function of PU beam height in APR (Figure 4).

Operating conditions in an WH, especially for forklifts in aisles, generate potential hazards of forklift’s impact on APR. In order to eliminate impact effects or to reduce them to an acceptable level, different approaches and solutions could be implemented. They could be related to forklifts and elements of APR structure. On the *forklifts*, aiming to avoid impacts, some of precise guidance system in rack aisle could be implemented; as well

as an equipment for precise PU storage/retrieving. On *pallet racks*, different approaches of upright frame element protection are present (but also with influence on aisle width and obviously on technological WH solution). Some of those protecting elements are shown on Figure 5 [9].

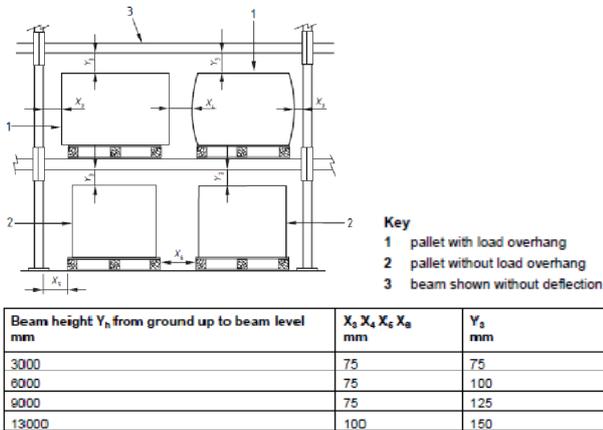


Figure 4. Horizontal and vertical clearances in a bay for trucks (EN 15620)



Figure 5. Some protection elements of upright frames.

One of the manners of upright frames protection from the forklift contact impact is construction change. It is done by construction change of lower section of upright frame (Figure 6), which decreases the endanger zone during the maneuver of the forklift. On the other hand, this change significantly influences additional requirements of rack construction, and therefore on the price itself.

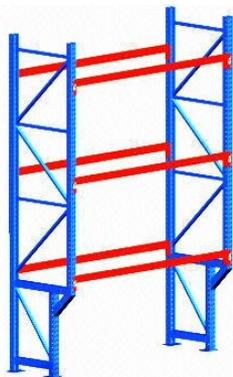


Figure 6. Look of rack construction with changed lower section of frame

[<http://firebirds.manufacturer.globalsources.com/si/6008802175854/pdtl/Warehouse-shelving/1028890308/Storage-Rack.htm>]

Implementation of the rack construction solutions consists of several aspects. The rack element supplier has to fulfill requirements of technological project of WH construction, as well as the requirements related to the material quality and manufacturing process, which is verified by appropriate standards and attests (i.e. ISO 9001). After the element delivery, adequate implementation is necessary, which requires appropriate supplier's experience, respecting project solution and conduction appropriate controls of construction tolerance (EN 15620, pages 19 and 20). Special attention is given to construction stability checks, rack anchoring (by quality, position and anchor number) etc.

### 3.3 Facility

Within technological solution design, the WH project overall (as well as its' elements apiece) has to be primary in accordance with APR solution project and applied forklifts. By doing so: „Clearance to building parts For mobile storage equipment the distance to the walls parallel to the driving direction shall either be between 0,05 and 0,18 m over a height of minimum 2 m or at least 0,5 m. The clearance of 0,5 m shall be measured from the most protruding part of the wall. Near to the ground rails or parallel to the ground rails no slab settlement joints are allowed.” [9].

The facility floor requires precise design [5], which has to consider the floor loading, rack type and flatness. From the tolerance aspect, the facilities need to fulfill the requirements from EN 15620, (point 5: Floor Tolerances).

The facility with its' own solution may influence racks and forklifts performance. In this domain, the facility should fulfill the environmental requirements (temperature, humidity, atmosphere aggression, earthquake etc.) [9]. Besides mentioned, other factors as well may influence warehouse process: lightning level of certain area, number of exchange rate related to air ventilation, etc. which can have impact on construction solution.

### 4. APR EXPLOITATION

In APR exploitation, safety analyzes should include, besides already described factors for the WH design, some other factors as well. As important factor of overall safety, the man himself is included in WH process realization in the rack area, as well as additional safety accessories on the internal transportation paths. In this chapter, each of them will be a subject of short review.

When the **goods** are analyzed from the safety aspect, for the WH process it is necessary to provide that PU fulfill requirements of safe workflow. This is primary related to the pallet correctness, pallet load stability, PU dimensions and mode of stacking goods units (especially with PU with mixed goods types). If some of requirements in this domain isn't fulfilled, these PU should be treated with special treatment (requirement for repair, processing, special WH area, etc.).

During the exploitation, the **facility**, WH and its' elements (floor, lightening, ventilation system, safety equipment, signalization, etc.) have to meet limits defined by the project. This is acquired by appropriate goods housekeeping and maintenance.

*The facility floor* must be properly maintained, for the reasons of safe movements and flow of RM equipments. This consists of the floor flatness checks, removal of any damages (cracks, deflections, etc.), hygiene maintenance, etc. *Lightening* must meet appropriate requirements during the exploitations (change, cleaning of light sources). The facility itself and its' elements through the *air conditionig system* must provide predicted working conditions (temperature, humidity, protection of atmospheric precipitation, sealing, and other).

The important safety aspect is also appliance of *signalization* – horizontal, vertical, and light signaling. Besides signalization, appropriate appliance of *additional safety equipment* is also significant, such as mirrors in the spots of decreased visibility, flow crosses related to movement of RM equipment and employees, etc.

#### 4.1 RM equipment

For the WH working process, **racks** are subject to different influences which might exceed tolerances determined by project solution. This concerns, above all, following:

- overload of construction elements (which is unacceptable from the safety aspect),
- incorrect load distribution in the rack (for example, deviation from the recommendation for the easier PU are stored on upper levels, and vice versa), and
- beam height modification (mandatory consultation with manufacturer and/or supplier from the capacity aspect and appropriate tolerances respect).

If it comes to construction racks element damages, it is necessary to evaluate level of damages by the authorized person (inspector or competent persons for the WH equipment safety). Deformation

level classification is done in accordance with EN 15635 (Figure 7a, 7b).

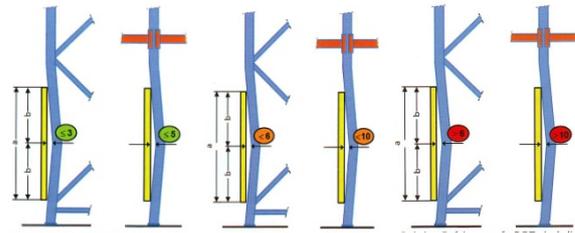


Figure 7a. Upright frame deformation level classification

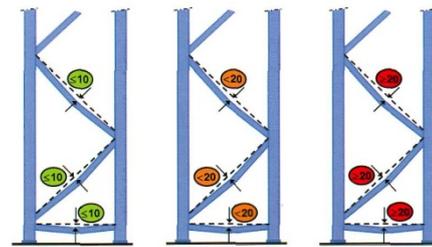


Figure 7b. Frame bracing deformation level classification [3]

Certified person (company) evaluates damage level and classifies it accordingly to CEN code in three damage levels (color highlighted): red, yellow and green risk level – Figure 7a and 7b [3].

For *red risk* instantaneous offloading of PU from the racks is required and adequate repair (commonly change) of damaged rack, before further use;

For *yellow risk*, adequate repair or change of damaged part within the shortest time period is required, where use of rack is possible until the repair is done; and

For the *green risk*, neither load decrease of the rack nor element repair is required (damage is being recorded), whilst during the following control, the check of damage level change is being done.

For beam overloading, no deformation classification is considered (Figure 8) [3]. Allowed deformation is (according to EN 15635) given by the calculation  $d \leq L/200$ , where  $L$  is span of the beam (load carrying component);  $d$  mid span deflection.

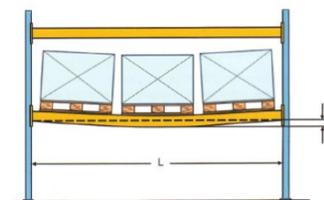


Figure 8. Inspection for overload damage to beams [3]

Rack construction check should be subject of continuous control, and for the purpose of working safety increase. In the literature, it is recommended

that this check is done at least once a year by certified person/company, and visual check to be done once weekly [3]. Also, in case of intervention on rack construction elements, it is necessary to provide proper repairs; in opposite case, this might be one of causes of unwanted event (fall, rack collapse).

For the *forklifts*, during the exploitation:

- the maintenance which provides their prescribed techno-exploitation parameters is necessary;
- eventual safety level increase by additional equipment (respecting solution in this area), such as: elements for drivers' protection (safety belts, cabin improvements, ergonomic control commands, etc.); for more precise driving and more precise handling of WH storage operations (i.e. cameras; forced guidance, etc.).

Due to complexity of determined tasks and great influence on WH process safety, the drivers of the forklifts must be specially instructed to:

- be informed about the significance of dangerous situations which might occur as a result of improper forklift use;
- act in accordance with regulations with eventual damages of object elements, racks or goods;
- visually check the load on the pallet and whether the pallets are proper;
- properly PU handling (during driving, lifting/lowering) aiming of forklift stability;
- properly dispose the pallets in the cell (which provides regular position of PU related to the beam - laterally and by depth);
- respect required lateral tolerances while positioning the PU in rack cell.

If the warehouse processes are not included in WMS, responsibilities and tasks of forklift-drivers are being extended on the assignment plan as well (storage and retrieval) with respecting of rack load limits at the same time. Due to all mentioned, the choice of fork-lift drivers (respecting all necessary psycho-physical characteristics), permanent renewal and improvement of their knowledge and skills must be adequately conducted. Therefore, these aspects must be the subject of continuous and appropriate checks.

## 5. CONCLUSION

Safety of warehousing processes is becoming more and more complex and important and has to be treated from different aspects. In this paper, the safety is analyzed with the focus of APR appliance, as the most common technology for PU. Also, in this paper, for APR, factors of safety in design, implementation and exploitation, as well as actual regulations, standards and recommendations are included. They provide improvements of project solutions and daily work processes, according to higher safety level with the appliance of APR. Clearly, questions in the domain of safety require further analyzes and improvements, as well as accidents analyzes (causes and consequences) in all WH segments. This is continuous process which has a special significance for logistics. It could be concluded that logistics experts have specific and important role in this field.

## ACKNOWLEDGMENT

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**Part V**

**QUALITY MANAGEMENT AND  
PERFORMANCE MEASURES IN  
LOGISTICS**

# ANALYZING THE EFFICIENCY OF DRY BULK CARGO HANDLING AT THE INLAND PORT TERMINAL USING SIMULATION AND DEA

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**Abstract.** *With the purpose of planning cargo handling, analysis of terminal for dry bulk cargoes has been done and the proposals for capacity increase have been given in this paper. Three different scenarios of its treatment have been proposed and each scenario demands involvement of certain labor force, and main and auxiliary loading/unloading equipment. Simulation models of the proposed scenarios have been developed in this paper, with the purpose of analyzing measures of effectiveness of terminal for dry bulk cargoes, and examining their influence on terminal capacity. Besides the simulation results analysis, the analysis of efficiency of the proposed scenarios of cargo handling using Data Envelopment Analysis (DEA) method has been done. DEA method gives possibility of observing the efficiency of the proposed scenarios and their sub-scenarios of dry bulk cargo handling.*

**Keywords:** *dry bulk cargo handling, inland port terminal, data envelopment analysis.*

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## 1. INTRODUCTION

One of the biggest challenges that port authorities are facing today is decreasing the vessel turnaround time. One of the ways to increase terminal productivity is to decrease the time vessels spend waiting to be served. The goal of the port management is to have a terminal that provides efficient and competitive service with high quality and low prices.

The goal of this study was to examine and plan, using simulation modeling and Data Envelopment Analysis (DEA) method, dry bulk cargo handling process at the Port "Danube", Pancevo [6]. The first objective was simulation modeling and analysis of dry bulk cargo handling, and calculation of measures of effectiveness (MOEs) for the terminal operation based on the simulation results. The second objective was application of DEA to calculate the efficiency of proposed scenarios and their sub-scenarios taking into consideration number of workers, utilized equipment and observed MOEs.

In this study, pushed barge convoys were used on inland waterways to transfer dry bulk cargo to the berth. Loading and unloading was done using quay cranes. Thoroughly planned organization of cargo transfer to the storage area would contribute to the

decrease in total costs through shorter time that vessel spend on the berth, higher utilization of used equipment and the reduction in the total service time.

This paper suggested three different scenarios of planned cargo handling process, where each scenario requires employment of corresponding labor force as well as main and auxiliary reloading equipment. Simulation models of proposed scenarios were developed with the purpose of analyzing MOEs for the inland port terminal that is used for the handling of dry bulk cargo. Collected and analyzed MOEs were average vessel service time, average vessel waiting time, quay crane utilization, and packer utilization. Simulation models for eight sub-scenarios were developed for both first and second scenarios. More precisely, observed models included alternatives where one and two quay cranes were used for cargo handling, and the cargo was transferred to the storage area using two to five trucks. Cargo handling in the third scenario was done using one and two quay cranes. Transfer to the storage area was done by belt conveyer. Thus, this study modeled and analyzed the total of 18 sub-scenarios. In addition to the simulation results analysis, analysis of the efficiency of the proposed alternatives for the cargo handling was done using DEA methodology [3]. DEA method provides the

opportunity to measure the efficiency of Decision Making Units (DMUs) for the proposed scenarios and their sub-scenarios, including number of workers, number of quay cranes and average vessel service time.

## 2. METHODOLOGY

### 2.1 Proposed Scenarios for the Dry Bulk Cargo Handling

Ideas for the proposed alternatives came from the collaboration with the employees in the Planning and Development Sector at the Port "Danube" Pancevo. The plan was to handle dry bulk cargo, more precisely, the fertilizer, at the port terminal. Fertilizer was transported to the port as a bulk cargo using pushed barge convoys (in further text, referred to as vessels). Cargo was further unloaded from the vessels using port quay cranes placed on the berth. Although fertilizer came to the port as a bulk cargo, its further transport required packing it in the bags. Port management had a goal to conceptualize the fertilizer handling in such way that would maximize the efficiency of the handling process without slowdowns, minimize vessel turnaround time, and maximize the utilization of equipment. To achieve that goal, the port management was considering two possibilities for fertilizer packing. First alternative was packing in bags directly on the berth, and second alternative was packing within the storage area. In addition, transfer of the fertilizer from the berth to the storage area was done either using trucks of belt conveyer. Further fertilizer handling consisted of stacking/arranging bags on pallets, which were further, according to the outside requests, either moved to the storage or directly distributed. Each of the considered alternatives required employment of the certain labor force and main and auxiliary reloading equipment necessary for quality fertilizer handling and for efficiently operated port terminal. Number of employed workers was determined based on the used technologies and depending on the reloading equipment. Based on these requirements, three scenarios for the fertilizer handling were proposed. Their detailed explanation follows.

First Scenario: Fertilizer came to the berth of a port terminal on the pushed barge convoy by inland waterways. The packer was located on the berth, and the fertilizer was directly transferred from the barge into the packer's bin using quay crane. Packer is used to pack fertilizer into plastic bags. Bags were, further, manually loaded in a truck and transported to the closed storage area. Within the storage area, the truck was unloaded and, then, it returned to the

berth for next loading. Fertilizer bags were palletized in the storage area for the purpose of further distribution. Palletized fertilizer was loaded into trucks for inland distribution or stored in the storage area depending on the current demands. In order to collect data for the analysis, eight simulation models were developed. Keeping all other inputs fixed, number of quay cranes and number of trucks were varied. One or two quay cranes were reloading cargo from the barge to the packer's bin; and the number of trucks used to transfer cargo from the berth to the storage area was varied from two to five.

Second Scenario: Second scenario of fertilizer handling considered reloading fertilizer directly into dump truck using quay crane, and further transporting the fertilizer to the closed storage area, over the truck weight station. Within the storage area, the truck dumped the fertilizer. While returning to the berth for new loading, it stopped on the weight station. Further cargo handling was done within the storage area where the fertilizer was loaded into packer's bin using a loader. Bagged fertilizer was put on pallets. Forklift put pallets either onto the truck for inland distribution or stored them in the storage area, according to the current demands. Same as in the first scenario, eight simulation models were developed, varying number of quay cranes (one and two) and number of trucks (two, three, four, and five) keeping all other inputs fixed.

Third Scenario: Third scenario considered reloading the fertilizer, using a quay crane, directly on belt conveyer (the continuous reloading equipment). Using the belt conveyer, dry bulk cargo was transferred from the berth to the storage area; more precisely, it was transferred directly in the packer's bin. Same as in the previous two scenarios, fertilizer was packed in the plastic bags, palletized, and transferred using forklift, to either truck for inland distribution or stored into the storage area. For this scenario two simulation models were developed varying only number of quay cranes (one and two) while keeping all other inputs fixed.

### 2.2. Simulation Model Development

In order to compare proposed scenarios, simulation models for each scenario and sub-scenario were developed. The simulation is considered to be one of the most powerful methodologies for analyzing potential success of the proposed scenarios. The simulation provides the opportunity to experiment with infrastructure, technology and operations without any real investments. All models were tested on the corresponding numerical examples. In order to

analyze performance indicators of the observed port terminal, simulation models of proposed alternatives for dry bulk cargo handling were developed in the simulation software package Flexsim (Flexible Simulation Software, Version 3.0, www.flexsim.com). Initial assumptions for the simulation experiments were set up based on the information obtained from the Planning and Development Sector at the Port "Danube" Pancevo:

- Pushed barge convoys' interarrival time was represented with normal distribution with  $\mu=3$  days and  $\sigma=1$  day;
- Quay crane's unloading time was represented with normal distribution with  $\mu=360$  s and  $\sigma=60$  s;
- Time to pack a fertilizer bag was represented with normal distribution with  $\mu=3$  s and  $\sigma=1$  s;
- Speed of belt conveyer was  $v = 3$  m/s;
- Average truck's speed was  $v = 15$  km/h.

### 2.3. Measures of Effectiveness

In this study, following measures of effectiveness (MOEs) were defined and analyzed:

- Average vessel service time (time measured from the moment when unloading process starts till the moment when the last cargo quantity is transported to the storage area);
- Average vessel waiting time (average time that pushed barge convoy spends in the port till it is moved to the berth where it will be processed);
- Average quay crane utilization (the average time that quay crane spends unloading cargo divided by the observed time interval);
- Average packer utilization (the average time the packer spends packing fertilizer in bags divided by the observed time interval).

### 2.4. Description of the Proposed DEA Model

In this study, 16 alternatives for fertilizer handling, as DMUs, were evaluated. Eight sub-scenarios from the first and eight sub-scenarios from the second scenario were considered; whereas, the third scenario was not included in DEA analysis. The goal of port management was the employment of reloading equipment and labor force for the fertilizer handling in such way to minimize the vessel turnaround time and to improve the overall operational indicators.

Very important step in the DEA model development is proper selection of inputs and outputs. After correlation analysis and the analysis of how the change in inputs and outputs impacts the

efficiency of observed scenarios, the DEA model with two inputs: number of workers and number of quay cranes, and one output: the reciprocal of average vessel service time, was chosen.

## 3. ANALYSIS OF THE SIMULATION RESULTS

This study observed terminal operations in duration of 90 days [8]. Terminal operates in two eight-hour shifts. Within the observed time interval, and based on the assumed arrival rate, 23 pushed barge convoys with the fertilizer arrived at the port, and needed to be serviced.

### 3.1. Simulation Results for the First Scenario

Table 1 provides MOEs collected in simulation experiments for the first scenario.

**Table 1. MOEs for the first scenario**

	Number of trucks	Average vessel service time (days)	Number of serviced vessels	Average vessel waiting time (days)	Average utilization of quay crane I	Average utilization of quay crane II	Average utilization of packer I	Average utilization of packer II
One quay crane	2	5.64	16	13.6	0.91		0.38	0.38
	3	5.33	17	10.6	1		0.42	0.42
	4	5.32	17	10.6	1		0.42	0.42
	5	5.31	17	10.6	1		0.42	0.42
Two quay cranes	2	5.61	16	12.6	0.53	0.41	0.39	0.39
	3	3.94	23	0.54	0.73	0.60	0.55	0.55
	4	3.93	23	0	0.71	0.63	0.56	0.55
	5	3.92	23	0	0.70	0.64	0.56	0.56

Table 1 shows that using two quay cranes and four trucks for the first scenario gave the best results among eight observed sub-scenarios. Waiting time of the vessel was reduced to zero, number of processed vessels was equal to the number of arrived vessels within the observed time period, and utilization of quay cranes and packers was satisfactory.

### 3.2. Simulation Results for the Second Scenario

Table 2 provides MOEs collected in simulation experiments for the second scenario.

Table 2 shows that using two quay cranes and five trucks for the second scenario gave the best results among eight observed sub-scenarios. Similarly to the first scenario results, waiting time of the vessel was reduced to zero, number of processed vessels was equal to the number of arrived vessels within the observed time period, and utilization of quay cranes and packers was satisfactory.

**Table 2. MOEs for the second scenario**

	Number of trucks	Average vessel service time (days)	Number of serviced vessels	Average vessel waiting time (days)	Average utilization of quay crane I	Average utilization of quay crane II	Average utilization of packer I	Average utilization of packer II
One quay crane	2	7.20	13	20.5	0.77	0.32	0.52	0.52
	3	5.62	17	9.9	0.96		0.61	0.61
	4	5.63	17	9.6	0.99		0.63	0.63
	5	5.34	17	8.6	0.99		0.64	0.64
Two quay cranes	2	6.40	14	17.9	0.52	0.54	0.53	0.53
	3	4.30	21	1.6	0.72	0.69	0.65	0.65
	4	4.10	22	0.2	0.67	0.69	0.66	0.66
	5	3.91	23	0	0.69	0.69	0.67	0.66

**3.3. Simulation Results for the Third Scenario**

Table 3 provides MOEs collected in simulation experiments for the third scenario.

**Table 3. MOEs for the third scenario**

	Average vessel service time (days)	Number of serviced vessels	Average vessel waiting time (days)	Average utilization of quay crane I	Average utilization of quay crane II	Average utilization of packer I	Average utilization of packer II
One quay crane	5.35	17	7.9	1.00	0.42	0.42	0.41
Two quay cranes	4.70	19	5.1	0.67	0.49	0.49	0.49

MOEs displayed in table 3 show that demands for the fertilizer handling without vessel waiting times in the third scenario cannot be achieved using either one or two quay cranes. Improvements in the observed MOEs could be possibly done by changing the reloading characteristics of observed equipment, which would decrease the average vessel service time and average vessel waiting time.

**3.4. Summary of the Simulation Results**

Table 4 summarizes the two sub-scenarios (one from the first and one from the second scenario) that serviced the vessels without waiting time. The third scenario did not give any alternative that serviced the vessels without waiting time, and, thus, it was not included in this summary and in the further analysis.

**4. EFFICIENCY ANALYSIS USING DEA METHODOLOGY FOR DRY BULK CARGO HANDLING**

Based on the simulation results analysis, it can be concluded that first and second scenarios (employing four trucks and two quay cranes, and five trucks and two quay cranes, respectively) could

process the cargo without waiting times. Since the third scenario did not meet current demands for dry bulk cargo handling at the port terminal, it was excluded from the efficiency analysis using DEA methodology.

**Table 4. Sub-scenarios that serviced the vessels without waiting time**

Scenario	Number of cranes	Number of trucks	Average convoy handling time (days)	Number of handled convoys	Average waiting time (days)	Average utilization of crane I	Average utilization of crane II	Average utilization of packer I	Average utilization of packer II
1	2	4	3.93	23	0	0.71	0.63	0.56	0.55
2	2	5	3.91	23	0	0.69	0.69	0.67	0.66

The goal of DEA methodology application was to investigate the efficiency of proposed sub-scenarios for the first two scenarios, that is, to point to the combination of input and output values that provides the efficient fertilizer handling at the port terminal. Proper DEA model development depends on the selection of inputs and outputs and their correlation. In this study, the authors chose the model with two inputs: number of workers and number of quay cranes, and one output: the reciprocal of average vessel service time.

This study evaluated 16 scenarios for fertilizer handling process at the port terminal. Each scenario represents a separate DMU, as follows:

- DMU1: first scenario-1 quay crane and 2 trucks;
- DMU2: first scenario-1 quay crane and 3 trucks;
- DMU3: first scenario-1 quay crane and 4 trucks;
- DMU4: first scenario-1 quay crane and 5 trucks;
- DMU5: first scenario-2 quay cranes and 2 trucks;
- DMU6: first scenario-2 quay cranes and 3 trucks;
- DMU7: first scenario-2 quay cranes and 4 trucks;
- DMU8: first scenario-2 quay cranes and 5 trucks;
- DMU9: second scenario-1 quay crane and 2 trucks;
- DMU10: second scenario-1 quay crane and 3 trucks;
- DMU11: second scenario-1 quay crane and 4 trucks;
- DMU12: second scenario-1 quay crane and 5 trucks;
- DMU13: second scenario-2 quay cranes and 2 trucks;
- DMU14: second scenario-2 quay cranes and 3 trucks;
- DMU15: second scenario-2 quay cranes and 4 trucks;
- DMU16: second scenario-2 quay cranes and 5 trucks;

Software Efficiency Measurement System [9] (Software Efficiency Measurement System, LP

Solver DLL n.d.) was used to solve suggested DEA model.

Table 5 shows inputs and outputs, as well as calculated efficiencies for the proposed DEA model.

Efficiency measurement and analysis of the proposed scenarios and their sub-scenarios using DEA method was done in order to choose the most suitable scenario for the fertilizer handling process in the Port "Danube" Pancevo.

Based on the calculated values, shown in Table 5, efficient sub-scenarios (in terms of the number of employed workers, the number of used cranes and the average vessel service time) were DMU2, DMU3, DMU4 and DMU6. With the efficiency that equals to one, these DMUs represent boundary of efficiency. DMUs with the efficiency less than one indicate that there is a need to decrease input values so they can become efficient for given output.

**Table 5. The efficiencies of evaluated scenarios**

Decision Making Unit	Inputs		Outputs	Efficiency
	Number of workers	Number of quay cranes	Reciprocal of average vessel service time	
DMU1	30	1	0.1773	98.76%
DMU2	32	1	0.1876	100.00%
DMU3	34	1	0.1880	100.00%
DMU4	36	1	0.1883	100.00%
DMU5	32	2	0.1783	74.62%
DMU6	34	2	0.2538	100.00%
DMU7	36	2	0.2545	97.16%
DMU8	38	2	0.2551	94.48%
DMU9	34	1	0.1389	73.89%
DMU10	36	1	0.1779	94.48%
DMU11	38	1	0.1776	94.32%
DMU12	40	1	0.1563	99.44%
DMU13	36	2	0.1563	59.66%
DMU14	38	2	0.2326	86.13%
DMU15	40	2	0.2439	87.71%
DMU16	42	2	0.2558	89.37%

For example, the least value for efficiency was 0.59 for the DMU13, which means that in order to achieve the efficiency with the current output value, it is necessary to decrease inputs by 41%.

Basic CCR DEA model gave multiple units with the efficiency equal to one. However, this model does not provide the way to determine which of those efficient units is the most efficient. For the purpose of ranking these efficient DMUs, the method of super-efficiency was used [1]. The results are shown in Table 6. This method provides the way to rank the efficient DMUs, and to choose the unit with the highest efficiency.

The super-efficiency method enabled ranking among efficient units (DMU2, DMU3, DMU4, and DMU6) and finding the unit with the highest efficiency (DMU6). Specifically, the highest efficiency was obtained for the first scenario of dry bulk cargo handling with the employment of two

quay cranes and three trucks. Second efficient cargo handling procedure was also first scenario, but with the employment of one quay crane and three trucks; followed also by the first scenario with the employment of one quay crane and five trucks. The last ranked sub-scenario in terms of efficiency was the second scenario with the employment of two quay cranes and two trucks.

**Table 6. The rank of evaluated scenarios**

Scenario	Efficiency	Rank
DMU1	98.77%	6
DMU2	102.71%	2
DMU3	100.03%	4
DMU4	100.16%	3
DMU5	74.64%	14
DMU6	105.59%	1
DMU7	97.18%	7
DMU8	94.49%	8
DMU9	73.88%	15
DMU10	94.48%	9
DMU11	94.32%	10
DMU12	99.47%	5
DMU13	59.68%	16
DMU14	86.15%	13
DMU15	87.71%	12
DMU16	89.39%	11

## 5. CONCLUSIONS

This study developed simulation models and performed the efficiency analysis using DEA methodology of the proposed scenarios for the dry bulk cargo handling at the inland port terminal.

Various scenarios for the fertilizer handling were proposed; each scenario and its sub-scenarios required employing certain number of workers as well as reloading machinery. Since the new process was observed, it was necessary to determine all variables that had an effect on the reloading and handling of the cargo. The results of this research could help the port management to set up the initial equipment, and to aid in the further operational management.

Based on the proposed scenarios, simulation models were developed. First and second scenarios of fertilizer handling varied the number of cranes (one and two) and the number of trucks (two, three, four, and five). Third scenario, used conveyor belt instead of trucks, thus, only the effect of the number of cranes (one and two) on the collected MOEs was observed.

The analysis of simulation results pointed to the number of cranes and number of trucks which was necessary to use to process the pushed barge convoy without any waiting time, in other words, to determine the capacity of the port terminal for dry bulk cargo assuming that vessels do not wait for unloading. Handling convoy without waiting time in

the first scenario was accomplished employing two cranes and four trucks; while, for the second scenario, it was necessary to employ two cranes and five trucks. This indicates that the first scenario met the requirements with one less truck, that is, with fewer investments. Results from the third scenario indicate that convoy waited for unloading with employment of either one or two cranes. For that reasons, the third scenario was excluded from the further analysis. Further analysis of the third scenario in terms of the change in the number and characteristics of all participants in the proposed handling process could possibly decrease waiting time, decrease time for the vessel serving and increase the capacity, and could be the topic for future research.

The contributions of this paper are development of simulation models for the dry bulk cargo handling process at the port terminal, definition and collection of MOEs for various conditions, and establishing satisfactory operational management on the terminal. The analysis of the simulation results pointed to the problem solving dynamics (removing port bottlenecks) with the purpose of improving MOEs for the cargo handling in current conditions. Developed simulation models have practical application in water transportation and can be expended for further research to analyze diverse cargo types that are moved simultaneously in both directions (import and export).

For determining the efficiency of the proposed scenarios using DEA methodology, the number of quay cranes and the number of workers were used as inputs; the reciprocal of average vessel service time was used as an output. The application of basic CCR DEA model gave four efficient units (DMU2, DMU3, DMU4, and DMU6). Further, modified DEA model ranked these efficient units, and singled out DMU6 (the first scenario of fertilizer handling with employment of two cranes and three trucks) as the most efficient sub-scenario.

Hence, DEA methodology pointed to the first scenario that employed two quay cranes and three trucks in terms of efficiency; whereas, simulation results pointed to the first scenario that employed two cranes and four trucks. MOEs, from the simulation experiments, for these two sub-scenarios were close in value, except for the average waiting time. If three trucks were used, the waiting time for the pushed barge convoy was 13 hours, but when number of trucks was increased to four, the waiting time was reduced to zero. However, applied DEA methodology, regardless of waiting time, singled out

the sub-scenario that employed three trucks as the most efficient, because, compared to other sub-scenarios, it represents appropriate sub-scenario of dry bulk cargo handling process in terms of employed number of workers, used equipment and average vessel service time.

This paper used the original approach to analyze, model and optimize the efficiency of the dry bulk cargo handling process at the inland port terminal. Developed models can be broaden and practically applied to the process of handling other types of cargo. The analysis of inefficient DMUs and increase of their efficiency can be one of the future research topics.

## ACKNOWLEDGMENT

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## CREATING AND MEASURING LOGISTICS VALUE

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**Abstract:** *In the past, logistics has been mainly viewed simply as a cost that needs to be reduced. However, logistic is not only the sphere of rising costs, but the sphere of creating and increasing the value. Through logistic services and activities, in supply chain, added value of products is created. Two out of five primary activities in the value chain belongs to logistics. Logistics value is created through standard logistic services, value-added logistics services and specific logistics solutions. Consumption value, as well as shareholder value, is created in the logistics sphere. However, many companies are not aware of possibilities that logistics can offer regarding creation of value. Reality is that the majority of companies have millions of dollars hidden in their logistic operations. Their discovering would mean improved profitability. The value obtained through logistic activity should be measured and monitored, which is not the case in the most of real systems. The aim of this work is to present comprehensive approaches of creating and measuring values, different ones, obtained in the area of logistics.*

**Keywords:** *Logistics value, logistics services, logistics activities, value-added logistics services, logistics solutions.*

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### 1. INTRODUCTION

Harsh global competition is distinctive feature of contemporary markets. The logistics has become the key factor in a competitive struggle, as well as in distinguishing oneself in a unique and open market. Product Development Technologies are very similar or exactly the same for a long time, and therefore these companies are competing in improving both product performances and services by longing to provide superior customer added-value.

Logistics processes and supply chains are important sphere for creating product added-value. The more shortened product life cycle requires its fast and successful launching on the market. Within the existing product deployment and consumption on the worldwide market, this is not possible without the effective and flexible logistics and supply chain.

A significant part of the finalization of production process shifts from traditional manufacturing plants more towards the market, in related logistics centres and systems, where it is prepared for sale and adding value.

Secondly, logistic spheres have many hidden values and discovery of those values will achieve significant benefits. Most logistics systems work

with increased operational costs and unused labor capital, which are important resources of the value.

In order to conceive and utilize properly the possibilities that the logistics has to offer, literature and practice should pay attention more to the value gained through logistic activities and processes. This study aims precisely at the issue of creating and measuring the value in the logistics. First, this study deals with the role of the logistics in the value chain. Second, the study is related to creation. Third, attention is given to the measurement the value of logistics.

### 2. THE ROLE OF LOGISTICS IN THE VALUE CHAIN

The very term value initiates series of confusions and it is often unclear what that term represents precisely. It can be said that the understanding of this term has always been one of the questions that requires precise answer.

Socrates and his successors, Plato and Aristotle, where the ones who set root definition of this term. Their discussions were concerning the grasp of the term value as an integral part of human beings (concerning souls and virtues). Later, this term gained different meanings like: ethical/moral value, ideological (religious, political) value, social and

aesthetic value, economic value. A specific scientific field called Value theory was developed – it studies values and examines different approaches and ways in evaluating certain concepts, ideas, goods and products.

The concept of value has been in the center of trade and business marketing for a long time, where the primary focus is on the monetary or material worth and services products which delivered to the user and the customer. Michel Porter defined widely accepted instrument of competitiveness – the concept of value chain in [9]. Value chain describes an organized set of activities through which the product passes and with each activity it gains a certain value.

According to Porter, activities that create the value in chain, in a broad-sense, can be divided into two types – primary activities and auxiliary activities, as shown on Figure 1. Primary activities in the value chain are: inbound logistics, manufacturing, output logistics, marketing and after-sales service. These activities are included in a concrete design as well as in creating the product value. Auxiliary activities are: procurement, technology development, Human Resources management and systems infrastructure.

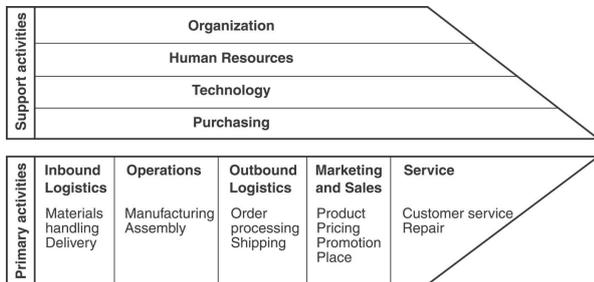


Figure 1. Value chain [9]

Two-out-of-five primary areas fall to logistics and logistic services, which clearly indicates the role and importance of logistics in creating a final value. Term inbound logistics relates to activities like procuring the company with raw materials, half-products and production services, and term output logistics relates to logistics activities like distribution and disposal of final products within commercial markets.

### 3. CREATING LOGISTICS VALUE

In the logistics sphere there are significant possibilities for creating value [6]. Logistics value can be created through: standard logistics services, additional logistics services and specific logistics solutions (Figure 2).

Standard logistics services which include transportation, storage, reloading, shipping services, etc. create spatial value and time value of the products. Spatial value is created by changing the location of the products. More precisely, by meeting customers need to find the products on demand locations (ready for sale, usage and consumption), a new product value is created. So, for example, the final products have one value when they are in a factory warehouse, another value when they are in stores, and the third one when they are in a consumer apartment.

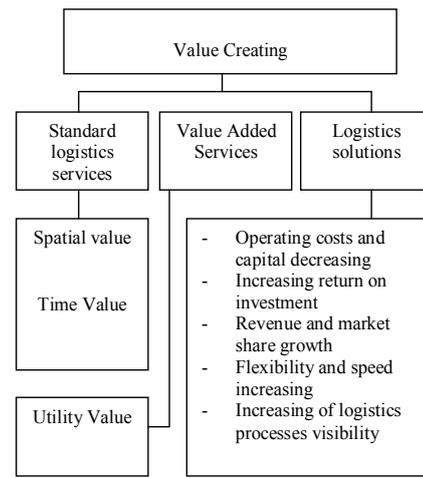


Figure 2. Different ways of creating values in the logistics

Time value is created by making the products available at a specific time and place. Spatial change, i.e. spatial adjustments to customer demands, is not the only thing that is important – occurrence time for this process is also important. The main point rests in the fact that customers receive their product at required time which increases the overall value of the product.

Additional logistics services (Value Added Logistics) contribute to creating and increasing utility value of a product. Logistics systems change the ways goods are represented (packaging, repacking, marking), product finishing (finishing touches, assembling, installation), product refining process, qualitative and quantitative transformations, quality increase, whereby the overall value of the product is changing significantly. Depending on the type of the product, in logistics systems, there are many processes like drying, ripening, cleaning, freezing, and product refrigeration are developing, whereby utility value certainly changes.

Specific logistics solutions that logistics providers offer can significantly increase the value by: reducing the operational costs and required working capital, improving the return on investment,

increasing revenue and market share, increasing flexibility and the speed of logistic process implementation, and also by increasing the visibility of logistic processes. Through the improvement of logistic processes operational costs, such as transportation, storing, inventory, transfer, administrative costs, etc. can be reduced significantly. By increasing the inventory turnover, reducing the safety level of inventory, improving the cycle time and striving for perfect deliveries, working capital requirement can be reduced. Reducement of working capital requirement is the primary interest in the company, as it is directly related to shareholder value increasement. Through better resource management, efficient flow of the logistics processes and better capacity usage it is possible to improve the Return On Assets (ROA) directly. This is very important because companies often have millions of dollars hidden in their logistics operations. High-quality logistics services and perfect procurement and delivery realization contribute to increasing market share and revenue growth, a time value and overall value. The need for flexibility, agility and the speed of logistics process implementation is greater than ever. By improving these attributes, the value increases significantly. Accomplishment of global visibility logistics processes in real time is powerful value creator through inventory reducement, that is, working capital and operational costs reducement, and customer service improvement.

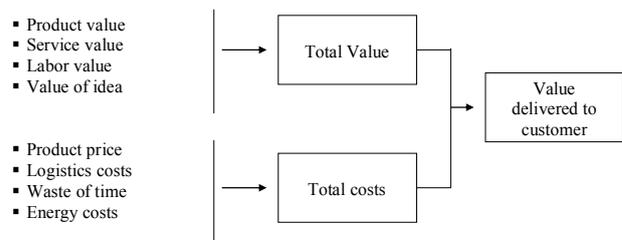
Creating the value of logistics needs to be viewed in two key perspectives – customer's perspective and shareholder's perspective.

### Creating value for customers

The determinants of customer delivered value means are differences between the perceived benefits of the purchase and overall costs relating to that purchase. Perception of the total value or benefits is a result of individual element assessment: product, service, staff and real idea, while the overall costs include the purchase price of product, logistics costs, resource cost and energy, as well as time-loss (Figure 3).

Obviously, logistics has strong impact on both components of value. High-quality logistics services directly attract customers and increase the perception of the purchase benefits. On the other hand, effective logistics strategies and technologies provide reduction of logistics costs, that is, the overall costs. For these reasons, logistics is considered to be very effective tool in creating and increasing the customer value.

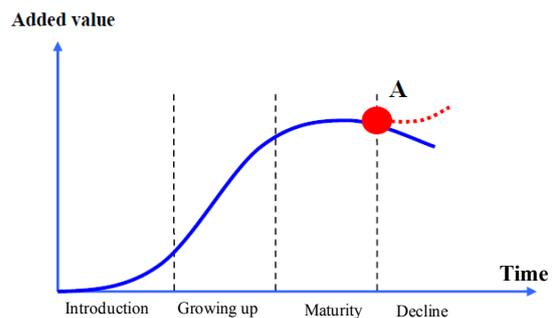
However, it should be considered that the perception of customer value is usually based on added-value services and specific logistics solutions. In principle, standard logistics services are granted. For these reasons, companies and provider that offer logistics services should long for providing services that give a value to a product, and to offer specific logistics solutions.



**Figure 3. Creating the total delivered value to customers (adapted from [3])**

It should be considered that the real value represents the dynamic concept, which changes a lot through the time. What is now considered to be an added value, tomorrow can be a standard service pack. For these reasons, creating the value within logistics services and solutions should be observed through service life (Figure 4).

New services, ideas or solutions create significant added value until the offer stays unique, that is, until it is copied and/or improved by competition – when that logistic package or logistics solution becomes the part of market offer, take the character of the standard offer and stops being the source of users' value perception.



**Figure 4. Creating an added value through logistics service and solution lifetime [13]**

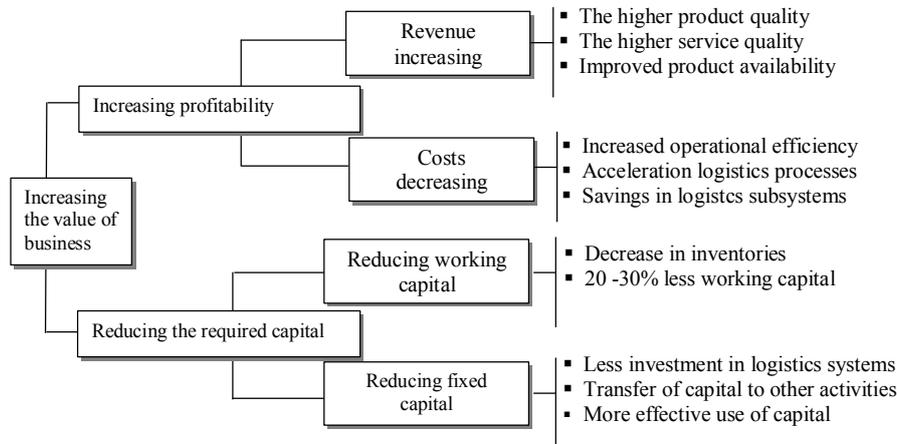
In general, the greatest potential of creating added value lies in the phases of introduction and growth of new services, ideas and solutions. In the maturity phase, due to the diffusion of the identical or similar offer on the market, users question the relevance of added value. If a provider do not arrive at inovative ideas, logistics services and solutions, any potential of creating the added value will be lost. For example, Point A shown in the graph (Figure 4)

represents the moment when a company needs to make innovations in its offer and focus its business on other services and solutions.

**Creating value for shareholders**

In addition to creating and making value for customers, logistics and logistic service significantly contribute to increasing business value (shareholder value). Business value increment can be achieved by increasing profitability and/or reduction of working capital (Figure 5).

Better profitability can be achieved by increasing revenue and reducing the overall costs. Revenues can be increased by improving product quality and delivery service, that is, better product availability, and costs can be reduced through greater operational effectiveness, logistics process acceleration and savings on logistical subsystems. Reduction of required capital is achieved through reduction of working capital (reduction in inventory levels, faster working capital, etc.) and reduction of fixed capital (more effective capital usage, less investments in logistic systems and transfer the capital in other businesses).



**Figure 5. Improving shareholder value (adapted from [1])**

**4. VALUE MEASUREMENT**

Logistic providers have to measure value offered to their customers in order to realize adequate profitability. The customers cannot be expected to analyse the offered value themselves and that they would be ready to pay for it. It is not enough just to list the superior attributes of quality, but the higher level of logistic service should be transferred into financial benefit. Besides the customers, the value realized in logistics should also be presented to the management of the company. It is easy for the management to ignore and underestimate the importance of specific logistic solutions when the logistics functions well. Everything mentioned above leads to the conclusion that the value created in the area of logistics should be measured both internally and externally, along the whole supply chain.

Marketing literature includes different approaches and methods of value measurement. Thus, for example, in [7] give the following key value measurements: customer satisfaction, Customer Value Added –CVA, total cost analysis, profitability analysis, strategic profit model, shareholder value analysis.

The value obtained through logistic activities can be measured in accordance to: spotted value and costs, quality, price and time; basic and added value; competition and stockholders value.

From the customers point of view, the value is, mainly, defined as the ratio between spotted benefits and total costs. In [2] author says that the costumers value can be presented in the following way:

$$\text{Customer value} = \frac{\text{Benefits perception}}{\text{Total costs}}, \text{ or}$$

$$\text{Value} = \frac{\text{Benefit}}{\text{Costs}}$$

Naumann implies that the customer establishes the perception of utility and costs on the product and customer service [8]. When spotted utilities are divided by spotted costs and risks, the value expected by the product/service consumer is obtained:

$$\text{Value expected} = \frac{\text{Value perceived}}{\text{Costs}}$$

where:

*Value perceived = Product attributes + Customer service attributes*

*Costs = Transaction costs + Product lifecycle costs + Risks*

From the marketing point of view, the value presents the ratio between realized and expected quality and it can be presented in the following way:

$$\text{Value} = \frac{\text{Realized quality}}{\text{Expectation}}, \text{ or}$$

$$\text{Value for customer} = \frac{\text{Quality x service}}{\text{Costs x time}}$$

Gale also connects market perceived quality (the quality of both product and customer service) with the extraordinary value for the customer, where the value has been defined as the quality perceived on the market which is aligned with the product price [2]. According to this author, the value is equal the quality comparing the price, where the quality includes all the attributes, except the price. This author also says that both the product and customer service have relative quality, price and value.

According to [4] "customer value" (CV) is results of "core value" (CV) and added value (AV), as shown below:

$$\text{CPV} = \text{CV} +/- \text{AV}$$

Core Value, defined by Grönroos, is shown as the benefit of basic solution in accordance to the price paid. It can be said that the core value has been materialized through a product or an offer as per retail price. In [14] author defines perceived consumer value (CVP) as general customer estimate of benefit according to invested and profited, based on the offered product. basically, the customer estimate goes further than directly perceived satisfaction created by purchasing the product or service. According to [4], the relationship between the customer and service provider can significantly and indirectly influence the overall perceived value.

The added value, depending on the level of implementation into the product or service, can have positive or negative effect to the perceived consumer value. According to the logistics perspective, measurement of the added value resulting through the activities along the supply chain is particularly interesting. Authors in [5] derive the conceptual formulation of added value (AV) in the following formula:

$$AV = \frac{U \cdot A}{C}, \quad \begin{array}{l} U - \text{utility,} \\ A - \text{access,} \\ C - \text{cost.} \end{array}$$

The equation implies that the added value for consumers is diminished in the case when the product is not easily accessible when needed ( $A < 100\%$ ), and/or when the former scope is the same, even if the product has "perfect" utility ( $U = 100\%$ ). Some authors, such as Womack and Jones, present the added value as the ratio between the improved quality and the time with the price [13].

Since the value is the basic instrument for the competitiveness, it is interesting that the realized value is also measured regarding the competition. In this case, the CVA can be presented in the following way:

$$\text{CVA} = \frac{\text{Perceived value in actual company}}{\text{Perceived value in competitive company}}$$

The ability of creating values for shareholders is of key importance for company's surviving. Two most accepted opinions regarding the way the management connects company's performances with making shareholders values are: shareholder value analysis – SVA, established in [10], and economic value-added - EVA, established in [11]. The shareholders values are considered to be the most comprehensive measures.

Measuring of the added value created in the area of logistics is the precondition for improving the logistic processes and supply chain. It is important to mention that the measures and measuring can be connected with the company's goals and can be established via online logistic scorecarding system and reports, where the achieved results can also be easily connected visually with the achieved values. Thus, the measurements and results become easily available to the management and key participants in the logistic processes.

## 5. CONCLUSION

There are significant possibilities for creating the added value in the area of logistics. It is necessary for the logistics providers and the companies to be aware of this fact, to constantly monitor, follow and indicate the value realized through logistic processes and activities. However, in the real systems, there are various problems and obstacles regarding the creation and calculating the value. Such problems are most often the consequence of two facts. The first fact is that the great number of companies lacks

knowledge and experience in value analysis. The employees often have limited cognition of best logistics practice, or they have not the experience in introducing and applying logistic solutions and measurements. Operations and logistic management regularly lack the time for innovations, analyses and improvements. The other fact is that outsourced services offered by experienced experts and consulting companies, are both time and money consuming, such companies search for faster and cheaper solutions. Those solutions can provide short-term effects, but the added value should be observed through the whole life cycle of the specific logistic service or solution, and also of the customer.

It is important to develop methodological practice of discovering, creation and measurement of the value, that would include the specific things of the specific logistic system. It is better that the methodology results from the mutual work of consultants and logistic experts from the company. That way the chances for its comprehensive applying will increase, which would lead to achieving the expected results.

#### ACKNOWLEDGMENT

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## DRIVERS AND BARRIERS TO INNOVATIVE LOGISTICS PRACTICES

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**Abstract:** “Business as usual” way of practicing could be summed as energy intensive, inflexible mono-modality, often structured in a straight push flow that usually generates itself large amounts of production waste. In opposition to this “business as usual” definition, innovative practices are found. Innovation is not necessarily something new to the world but new to the user. Although research on logistics innovation is still in its infancy, efforts are being put on defining and identifying innovation in the logistics sector by professionals and academics worldwide. Innovative logistics practices, ILP, could be considered as a key piece of this necessary and on-going supply chain modernization. The purpose of this paper is to investigate ILP in the studied EU projects and to identify drivers and barriers for the implantation of the same.

**Keywords:** innovative logistics practice, drivers, barriers, EU projects.

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### 1. INTRODUCTION

Some experts explain “evolution in LP” as an anticipation to the dissatisfaction of the customer, which makes necessary the search for new approaches to the situation often based on model expectations rather than empirical, yet not available, results. These changes are described as purposeful and goal-oriented [1], which sometimes represent window options for “less suitable” or unsustainable solutions. The here-called “less suitable” unsustainable practices are often just old LP business models that are systematically applied in relevant stakeholders’ facilities until socio-economic factors become an unsolvable incompatibility to “business as usual”.

This definition of “business as usual” way of practicing could be summed as energy intensive, inflexible mono-modality, often structured in a straight push flow that generates itself large amounts of production waste. These practices shall be considered obsolete given the current technological improvements available and unacceptable from the sustainability perspective.

Contrary to this “business as usual” definition, innovative practices are found. It is interesting to remark that “innovation is not necessarily something new to the world but new to the user” [2]. Although research on logistics innovation is still in its infancy [3], efforts are being put on defining and identifying innovation in the logistics sector by professionals worldwide. Logistics innovations practices, ILP, could be considered a key piece of this necessary and on-going supply chain modernization. Logistic value chain that entails ILP at which flexibility, optimization and multimodality are some of the main desirable features. This paper aims to investigate about ILP and their interaction with the relevant stakeholders in order to identify drivers and barriers for ILP through EU projects.

Data collection method applied was literature review, i.e. review of 39 different EU projects that were of interest for study in the present LOGINN project in which authors of the paper are involved.

### 2. FRAME OF REFERENCE

ILP are currently gathering the EU attention as researchers and practitioners develop new business models across international companies with their

correspondent impact, and often, large competitive advantage increases. These stories of success are often shown by the media and awarded by public opinion, which establishes such innovative companies as good examples to the rest. This rebound effect is therefore a good business strategy nowadays. Such experiences are labelled as “best practice” by the experts. This term is still currently being developed, and could be summarized as a name to describe the most convenient ways of doing things to contrast “inferior” practices.

A “best practice” within ILP could be defined as a practice that is feasible, proven and known by its success, independently evaluated or that has entitled a strong high-level outcome testimony [4]. Through the analyses of these successful experiences, and the previous testimony of experts, it can be highlighted that supply chain represents significant opportunities for potential improvements [1], making of special interest to explore further the circumstances that contribute to the adoption of these practices.

Nevertheless, whether or not something is a best practice will depend on the context in which it is applied. The projects on which this research is based have been selected by their proven “best practice” implementation following this chain. All selected projects involve innovation [2], efficiency improvement and productivity increase for freight transport despite the large differences in the nature of each of them.

Some of the most relevant areas have been identified and classified as follows:

- E-Freight: the challenges arisen by societal development have created a new scenario for international freight transport. The determinant characteristic of eFreight is the maximisation of the benefits from information technologies.
- Co-modality: this array of modality is described in contrast to a seamless use of several different modes in one chain. Co-modality is a step further to achieve the efficiency and integration by smoothing the transit from one mode to another towards the optimal and most sustainable utilisation of resources.
- Urban Freight Transportation, UFT: these activities are concerned with delivering and collecting goods in urban centres. Urban freight deals mainly with the end of supply chain, being mostly configured by small loads in frequent trips and resulting in large quantities of vehicle kilometres.

- Intralogistics: describes the organisation, realisation and optimisation of internal material flows and logistic technologies along the complete value-added chain. These practices cover internal flows between hubs such as distribution centres, airports, seaports, etc.; as well as their related information flows.

Figure 1 summarizes the relevant key concepts that entail this classification.

<p style="text-align: center;"><b>eFreight</b></p> <ul style="list-style-type: none"> <li>• IT based</li> <li>• Information enhancement</li> <li>• Standardised</li> </ul>	<p style="text-align: center;"><b>Comodality</b></p> <ul style="list-style-type: none"> <li>• Multimodality</li> <li>• Compatibility</li> <li>• Flexibility</li> </ul>
<p style="text-align: center;"><b>UFT</b></p> <ul style="list-style-type: none"> <li>• Local solution</li> <li>• Air quality</li> <li>• Optimisation</li> </ul>	<p style="text-align: center;"><b>Intralogistics</b></p> <ul style="list-style-type: none"> <li>• Communication</li> <li>• Organisation</li> <li>• Optimisation</li> </ul>

**Figure 1. Key concepts of ILP practices**

This classification is maintained through the project and during the analyses of the ILP concerns for an improved experiences when targeting common drivers and establishing specific strategies to overcome barriers.

### 3. SURVEYED PROJECTS

- BaTCo
- BestLog
- C-LIEGE
- CASSANDRA
- CityLog
- CITYMOVE
- CIVITAS
- CODE24
- COFRET
- COMCIS
- DELIVER
- E-Freight
- ECOSTARS
- eMar
- EUROSCOPE
- FLAVIA
- FREIGHTWISE
- FREILOT
- Hinterport
- iCargo

- Logistics for Life
- SAFEPOST
- SCANDRIA
- SMARTFUSION
- SPECTRUM
- STRAIGHTSOL
- SUGAR
- SULOGTRA
- SUPERGREEN
- SuPorts
- Support
- SURF
- SUSTRAIL
- TAPAS
- TRAILBLAZER
- TRANSITECTS
- TURBLOG
- UNDA Project
- VIACOMBI

#### 4. FINDINGS

Across the EU territories in the scope of the research, different countries and types of projects have different relevance. From a total of 39 different projects, 41 projects accounting, since some were divided into subprojects. Table 1 illustrates the occurrence of the different types of ILP relevant for the research. In this table, it can be seen how UFT related projects are a great interest to the different stakeholders and a sector where efforts still need to be put, specially caused for urban health and safety concerns [5].

**Table 1. Number of exclusive (specific for certain ILP) and related projects to each type of ILP**

Type	Exclusive projects	Total related projects
E-Freight	6	13
Co-modality	8	16
UFT	16	19
Intralogistics	1	5

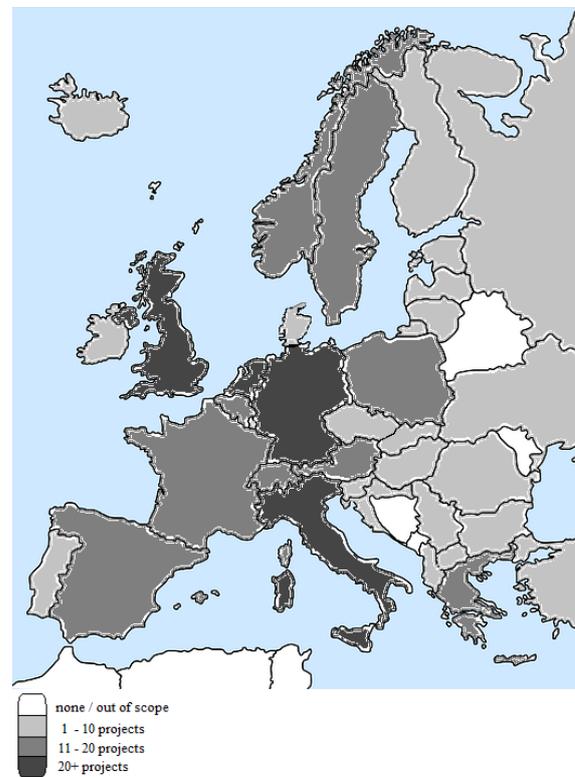
It is also remarkable how intralogistics projects have more presence when related to other types of ILP. This fact is sourced in the internal nature of intralogistics which makes this type of ILP of special interest in complete modernisation plans that are included often together with eFreight projects.

During the survey of the project list, it could also be noticed the following funding organisation's distribution, as in Table 2, with the predominant appearance of the European Commission. Following sections of the present research deal with the importance of this institution in regards to ILP.

**Table 2. Funding entities to ILP projects**

Funding entity	Number of projects
EC	29
ERDF	6
INTERREG IVB NWE	4
UNDA	1
BSRP	1

Moreover, a map of the occurrences of ILP relevant surveyed projects has been drawn as in Figure 2. Hereby, some resemblance with the main historical corridors can be highlighted. These historical via are the English Channel and the north-south corridor that joins Scandinavia with the Mediterranean.



**Figure 2. European ILP occurrence map**

Some other relevant countries are Poland and Spain. These territories, historically dominated by road traffic and with relevance for the access to Africa and Asia, are of special interest as they would set an example for the modernisation of other European areas such as Eastern Europe. This modernisation can also be illustrated as in Figure 3 where the trends on ILP occurrence are shown by year.

ILP in Figure 3 is understood as the time development of LP where after a period of learning [6] from 1996 to 2008, finally the concept develops and gets the dimension of “best practice” (expressed as the larger number of relevant successful occurrences).

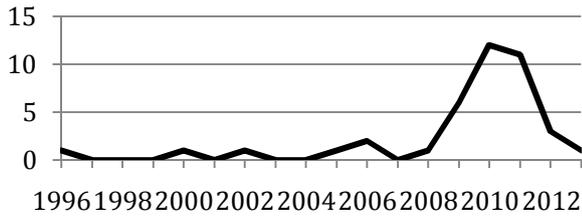


Figure 3. Time developing of ILP graph

#### 4.1 Summary of the drivers

Figure 4 shows occurrence of 4 main categories of drivers identified in the surveyed projects.

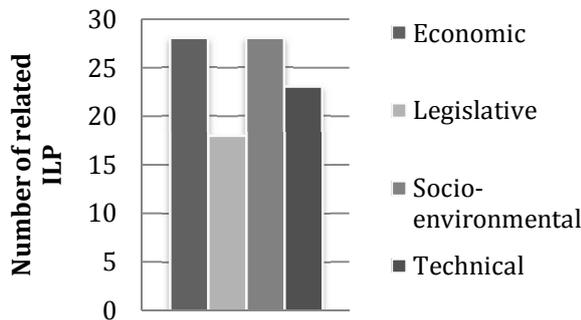


Figure 4. Drivers occurrences per type of ILP

It is worthy to highlight that socio-environmental concerns are of the same relevance as economic drivers.

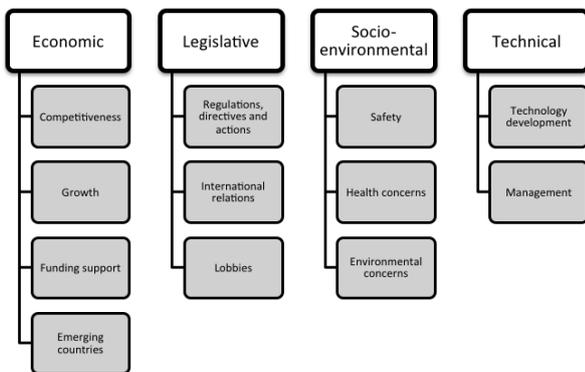


Figure 5. Drivers overview

#### 4.2 Summary of the barriers

Figure , illustrates on the accounting developed among the ILP selected projects. Standardisation and cooperation appear as common lacking aspects in surveyed ILP.

Standardisation lacks could be understood of part of the process of implementation of innovation where first experiences set the basis for regulations that tend to benefit and speed up the following experiences. On the other hand, lack of cooperation is an overall negative aspect in regards to ILP or the implementation of any sort of project due to the necessity of involved actors to work together. These

barriers are further characterised and analysed in order to reflect on positive overcoming experiences of the same and how to export overcoming techniques in order to benefit the entire ILP scope.

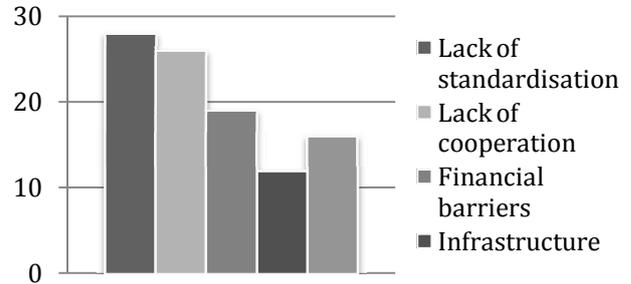


Figure 6. Barriers occurrence per type of ILP

### 5. OVERCOMING THE BARRIERS

The problem of spreading innovations and best practices is not new. For over 50 years, organisations have been aware of the paradoxes of innovation that despite the success in one location fail to spread in other environments and remain as “islands of innovation” [7]. As a result, efforts are duplicated, cost reduction in large scale predictions does not take place and knowledge is put in risk given the perceived market failure. The challenge for management lies here, in simultaneously coordinate what already is in place (staff, processes, infrastructure, customers) while implementing something “unknown” and place the right amount of resources in it [8].

Innovation is also associated negatively with declining productivity [9]. The probable reason behind this is the lack of results in forehand when advocating for the implementation of an ILP and the multidisciplinary projects difficulties that arise during these procedures that tend to be associated to innovation when they do in fact belong to the entire functioning of the sector. Innovation should be understood as an asset for behavioural change [9]. This change given the multidimensionality of the sectors involved (population, organisations, technology or methodology) is expected not to happen instantly, fact that must be act in detriment of ILP. These factors are compiled in Figure 7.

A good strategy towards conquering the behaviour of population starts by enabling information and making a great effort of auto-criticism and transparency. Once population trust a technology and in the power of decision making of their representatives, it is more likely to obtain external support, especially in policy makers, industry and university. And when the framework is established, it is time to maintain the level of trust and take action with optimized timeframes and

projects that will not wear off the effects of the support achieved so far.

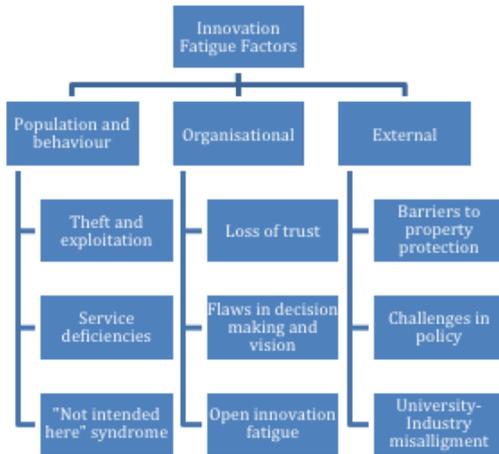


Figure 7. Innovation fatigue factors [9]

One solution is in peer-to-peer learning based on open scenario networks, at which the users must contribute equally sharing their past mistakes and performance indicators as well as the methods by which they have achieved a successful monitoring of the same [7]. The practice of sharing mistakes is proved as value adding practice.

There is a need for top-level support, as it has been proved that technical and supply chain management solutions do exist and are scattered in a broad band of available products with more or less successful experiences. Anticipating the policy measures in high spheres and demanding engagement from the member countries could entail a powerful driver towards ILP diffusion. This is especially remarkable for the development of emerging European economies given the great economic growth and the investments that take place continuously. It is in these economies where all factors are currently aligned and only need political and public involvement in order to achieve sustainable best practices. This has a great positioning opportunity for the future that could set the bases for emerging economies all over the world.

Last but not least, international culture difference related barriers monitored during this project have been already targeted by the experts. It is recommended to prioritise a healthy organisational environment focusing on emotional intelligence and targeting the differences between sectors, groups or individuals as tools towards overall organisational strengthening rather than obstacles [10]. Local/regional specific knowledge transfer teams are highly recommended to achieve the best results out of the integration policies.

## 6. CONCLUSION

With current rates of technology and supply chain techniques development, it must be highlighted that solutions are abundant and in place for practitioners to implement. As of the drivers that may help the development of the projects, it has been found that there is a wide spectrum of funding support (private sector, EU programs, and regional developing programs) and research is carried out continuously by academia.

The EU is a relevant stakeholder in the field of ILP, as it represents the main public funding scheme (with several programmes in place) as well as a source of academic support and a great ally in term of information and networking support. Despite this great interest by the lead authorities of the Union, it has been observed that there is a gap of commitment at high national levels. This is expected to occur given the nature of EU policies regarding the socio-environmental advantages of ILP. When the documentation in place is only recommending to take action, while there is a lack of involvement from the economic sector (decreased implementation of ILP since 2009 with the start of the economical EU “crisis”) the effect that results is a delay in the projects or in their continuity.

In regards to the political context of EU, it has been highlighted that there is a need for long term policy measures of the administrations in regards to socio-economic prospects. It is fundamental to regard the long term perspectives and uncertainties as a constructive foundation for the competitive advantages of ILP already nowadays and in the long run. The featured narrow perspectives, associated with political residence time, are not compatible with the great involvement and investments necessary for the spread of ILP across the European territory. Despite efforts are put in place nowadays in the shape of socio-economic framework policies, the pace at which they happen is slow for a complete sync. This policy-making period should be speed up and count with an increased compromise from the union members in order to start this long-term venture. Effects will not be immediately foreseen in many cases and in others implementation occurs without accurate predictions, reasons why long term perspectives must be in place and become public strategies for the entire society and industry to benefit from it.

Public opinion often plays an important role in supporting technology and industry’s vision towards implementation. Population needs to be well informed during the design of ILP in order to engage their support rather than discomfort at the same time

that transparency is reinforced in all levels of society and administration. The power of good press references must not be underestimated.

#### ACKNOWLEDGMENT

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## LOGISTICS PERFORMANCE IN POSTAL LOGISTICS CENTERS

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***Abstract:** Postal logistics centers (PLC) as places of the concentration of large quantities of shipments, have a function of collecting and distribution in the postal network and represent a important link in the delivery of shipments between the sender and the recipient. Technological processes that are carried out in these centers, arising from defined business objectives of postal service and generally include: sorting of postal shipments, organizing the transport and provision of postal and logistics services. As the logistics and postal processes are integrated in the realization of technological processes of postal services, this paper represent the first step to extract the measurers of logistic performances of postal operations in the PLC. Measuring logistics performances the efficiency, productivity and quality of functioning of the PLC as a logistic system, is measured, and presumption is created for their use when planning and defining future goals of PLC and the global performances of logistics processes in the postal service.*

***Keywords:** postal logistics centre, postal items, logistics process, logistics performances.*

\* Corresponding author

### 1. INTRODUCTION

Postal service plays a significant role in the development as a leading commercial and financial region, providing communications between individuals, business and government. In recent years, postal operators are facing with the challenges of rapid technological development, market liberalization, segmentation and increasing competition. In such conditions, the industry has evolved to include traditional post (like package and mail delivery), courier services, freight services and e-services [6], and leading European postal operators (such as: Deutsche Post DHL, La Poste i Royal Mail) have expanded their operations in the logistics sector. This development of the postal sector is conditioned by the rapid development of e-commerce, which, among other things, includes a strong logistics.

### 2. THE STARTING POINT AND PAPER GOALS

The structure of the postal network and the characteristics of the process in the postal service, makes from postal network, a complex and dynamic

system. Post centers are an important link in the system with the task of implementation of one phase in the delivery of shipments between sender and receiver. According to market-oriented and customer-driven development of postal operators, many of the traditional postal centers, expanded service offerings and grown in postal logistics centers (PLC-s).

A Logistics Centre is the hub of a specific area where all the activities relating to transport, logistics and goods distribution – both for national and international transit – are carried out, on a commercial basis, by various operators [5]. The PLC logistics processes are realized over different postal items as a unit load.

Bearing in mind the global determinants of postal operators and the structure and characteristics of the technological process of postal services, it is clear that the logistics as an instrument of differentiation (logistics as a marketing tool), and rationalization (as a method of reducing logistics costs), is an integral component of the business strategy of the company.

The process of transfer of postal items from the sender to the receiver is determined by the price and quality of service of postal operator. Logistics performance, i.e. efficiency, productivity and quality

of logistics processes, may be expressed with appropriate logistic performance, and represent a result of individual logistics processes. Following the hierarchy of relations, on the same principle, the effect of the PLC, could be described by performances, which are result of performances of individual logistics activities and processes.

The aim of this paper is to give a suggestion of logistics performance, and measurers of postal operations in the PLC, which could potentially represent the foundation for internal controlling and possibly of benchmarking in postal logistics.

### 3. STRUCTURE OF THE POSTAL NETWORK AND TECHNOLOGICAL PROCESSES IN THE POSTAL SERVICE

The key characteristics of postal services is reflected in the massive user demand for transfer of postal items, and the effect is realized through technological processes that generate physical moving of shipments with aim of their transfer to the recipient. From an organizational point of view, for the implementation of postal services that demands the market (national operators are conditioned to also to provide a universal service) it is necessary to establish a uniform postal network (on national and international level), the use of unique technologies and standardization of equipment. The structure of the postal network and its equipment is conditioned by the economic capabilities of operators, traffic volume, and in the case of a national operator, government influence on investment policies and development of postal services is very influential.

Elements of the postal network in Serbia are: post offices for providing customer service, postal-logistics centers and transportation systems.

As a units of postal network, PLC are located in the traffic hubs in order to achieve the concentration and diffusion of shipments on the geographical area that they cover. Establishment of postal network in PLCs gives them a key role in the concentration of shipments and processing of received of shipments and dispatch of mails. The main tasks of the PLC are: sorting of postal items, sorting of postal reloading units, transport organization, the postal and logistics services. According to responsibilities, PLC may be international (office of exchange), regional (the main postal center) and local (postal centers and transshipments points). There are also specialized PLCs designed to provide specific services, such as providing support to hybrid mail system, development of postal articles, fleet management, etc.

Routing of shipments (mails) is defined by the topology of postal network and type of connecting of postal network units, which is on the example of Post Serbia shown in Figure 1.

Transfer of postal items consists of the following stages: collection, dispatch, transport, arrival and delivery. Collection phase can be arranged directly or indirectly, depending on whether it is achieved through the counter in post offices, business premises of the user using postman or via of postal box or using self-service postal kiosk.

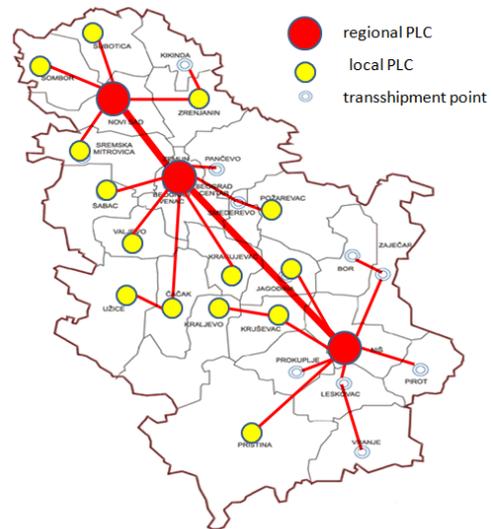


Figure 1. Topology of the postal network in Serbia [9]

The task of shipping is to prepare received items to the transport in direction of the destination post office or in the direction of the route of destination post office. Post offices for customers service achieve this phase dividing received shipments according to whether or not they are routed to: receiving post offices, units that belong to the PLC which belongs to the area of receiving post office, other units in the state, or they are intended for international land or international air traffic.

Transport of postal items is realized between dispatch and arrival of shipments to the destination PLC or delivery post office. In this phase directly or indirectly connecting is carried of all postal network units, from reception to the delivery of shipments using a wide range of transport vehicles. To achieve the most efficient utilization of available resources in the organization of transport connections appropriate forms of concentration and diffusion of items in the transportation chain, are applied. In the Post Serbia this phase of transport of postal items is carried out in the five transportation levels [8]:

- First level - transport shipments between designated operator (international service)

- Second level - the transportation of shipments between the PLC,
- Third level - transport between the PLC and the post offices which belong to the PLC,
- Fourth level - transport in the area of reloading –sorting post offices and
- Fifth level - which involves other transportation (per contract and internal documents of Posts of Serbia).

Arrival of postal shipments include taking over and processing of the mails of the PLCs or items in order to further delivery or dispatch of shipments. After the arrival of mails in the PLC shipments can be processed in order to prepare for delivery via delivery post offices. Also, PLC may only transit the conclusions to the destination post offices. After the arrival of mails in the destination post office there are processed and prepared for hand over.

The process of delivery, as the last stage in the transshipment of postal items, can be realized as a hand over (in the post offices, or through self-service postal kiosk) or delivery (at users address).

#### 4. TECHNOLOGICAL PROCESSES IN THE PLC AND PROCESS INDICATORS

Defining the tasks for processing postal items in the PLC, and from that setting the technologies and work organization is based on the division of relatively homogeneous species and categories postal items in respect of their processing. Therefore there are different processing methods for: ordinary LC shipments of standard sizes, AO shipments and non standardized LC shipments, recommended and valuable shipments, packages, express items etc. Treatment processes, as well as the possibilities of mechanization and automation differ significantly for specified groups. The first group (LC standard size) is numerically the most common and it is very suitable for automation application.

PLC realizes concentration and routing of incoming shipments at defined exit directions with restrictive time limit. In the PLCs simplified analysis of the PLC it can be considered PLCs basic function of redistribution of incoming mail flows to the output directions (Figure 2).

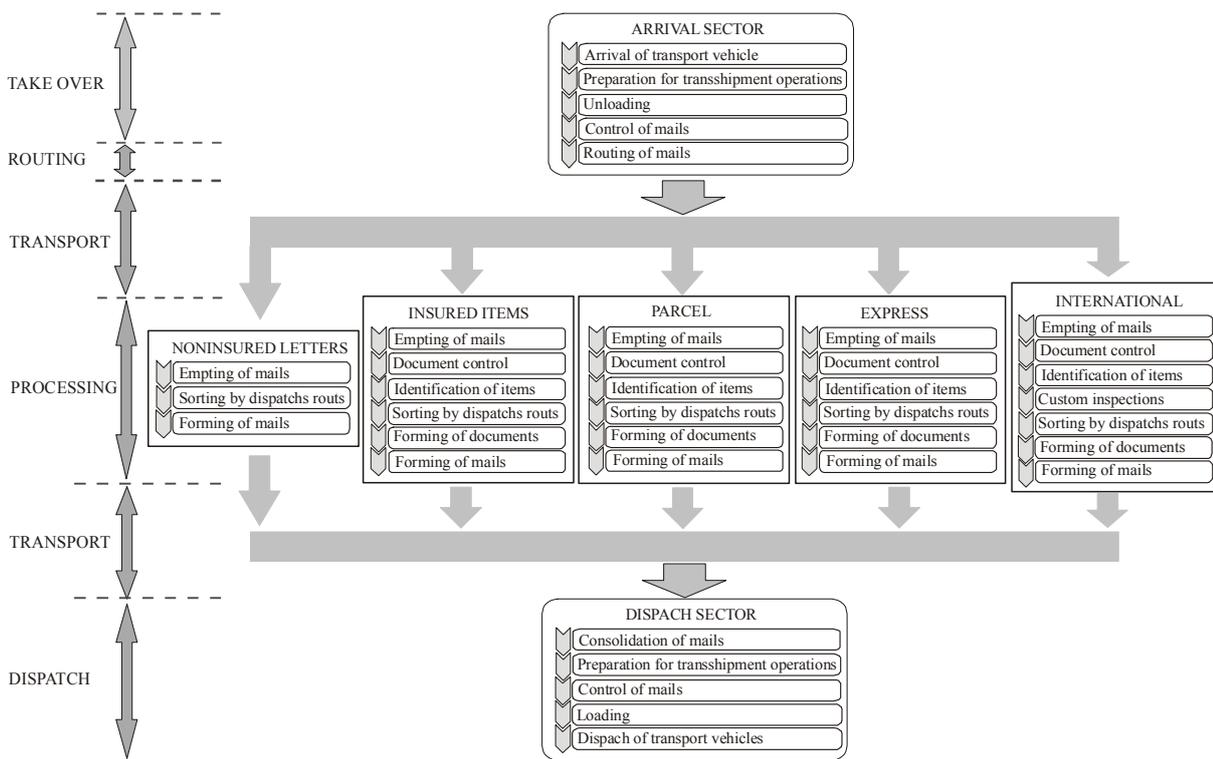


Figure 2. Flow of shipments in PLC

Input flows as independent values are the result of various external factors, while the output flows can be viewed as dependent variables which define the functioning of the PLC. Output flows are imposed by the limitations which PLC should fulfill

as a subsystem of a superior system of postal network. Generally, the shipments flow in the PLC can be described as follows: after the arrival of conclusions there are separated by type and opened, after that comes preparing shipments for sorting,

sorting by directions dispatch, and in the case international shipments submission to customs inspection, the formation of conclusions for the units of postal network organizationally belong to PLC or to other PLCs, the concentration formed of conclusions and loading in transportation vehicles. Quality of functioning of PLC can be viewed through the lost shipments, processing delays, rational use of resources and so on.

The efficiency of dispatch in the PLC is represented by the tendency to achieve the minimum number shipments sharing. The coefficient of handling multiplication is used to describe mentioned efficiency and it is determined as follows (1):

$$k = \frac{x + y}{x} \quad (1)$$

where  $x$  is the total number of shipments for processing, and the  $y$  is number of shipments that are two or more times sorted. The values of the above ratio which are less than or equal to 1.4 are considered satisfying.

Work operations within these phases are time-dependent by the type and category of shipments. The application of automated systems for sorting, opens the possibility of reducing costs and improving quality of shipping. Manual sorting has capacity about 2000 shipments per hour [13] while tens of thousands shipments per hour can be sorted in the automated systems. In addition to the significantly higher capacity achieved by automated systems they also have significantly lower degree errors. Taking into account the wide range of postal shipments, the most appropriate indicator of worker productivity are norm minutes.. Processes during the processing of postal shipments are standardized, i.e. there are defined norm minutes for different operations, which serve as a unit of measure for productivity. The ratio between actual norm minutes and total time is a measure of worker productivity.

## 5. LOGISTICS PROCESSES AND PROCESS INDICATORS

During the transfer of shipments from the sender to the recipient, numerous logistics activities and processes are detected: transport, transfer, processing (sorting), preparation for shipment, as well as design of all supporting information flows. Logistics processes in the postal sector represent range of logistics management activities: informational, technological, organizational and controlling and all have their goals which are

harmonized with the goals of postal service as a superior business system.

The effect of logistics processes as a series of successive and parallel logistics activities is measured through logistics performance. The goal of performance measurement and control activities in the logistics is to monitor logistics performance versus operating plan and in that way identification of opportunities to improve the effectiveness and efficiency [2]. Although there are many papers dealing with the study of logistics performance measurers [1, 3, 4, 10, 11, 12, 14, 16], in the literature, there is dispersion in the conceptual interpretation, coverage, methods of evaluation and grouping criteria. In the latest research in the field of logistics and supply chain, for the evaluation and monitoring of logistics processes, following performance classification is often used [7]:

- Financial performance,
- Productivity performance,
- Qualitative performance and
- Time performance.

The above classification is very convenient in terms of structuring, measurement and monitoring of logistics processes and in this work represent a base in the selection of logistics performance in the PLC.

In order to describe complex processes in logistic systems it is necessary to establish a hierarchical structure of the process, understand the relationships between processes and relationships between processes and performance, that is, it is necessary to logistic processes appear as a specific series of individual logistics activities and processes which can be quantified [15]. It is advisable to use some of the graphical techniques that take into account the time and space components of logistics processes. Defined set of indicators allows to establish a reference value level, determine changes in time perform verification of compliance of achieved and target values and identify opportunities for improvement.

Legal regulations which regulates the work of post, goals of postal service and competition in the market represent a framework for defining the objectives and tasks of the logistics during the delivery of shipment from the sender to the recipient. If we start from the global performance of postal services that are important to the user, such as the time of delivery and the price charged for the delivery, for each stage in the delivery it is possible to define lower level logistics performance or performance of individual logistics processes. By the same principle, and the effect of PLC as a node in the postal and logistics network can be characterized

with performance that are the result of the performance of individual logistics processes, which affect the global performance of logistics processes in the postal service.

Given the logistical processes that are implemented in the PLC (Figure 2) in Table 1 for each process is proposed list of measurers for logistics performance. Described process structure

and a list of measurers given as a suggestion can be adapted to the structure depending on the needs and circumstances of the business system. One must not forget that the PLC is a link in the implementation of the delivery of shipments, so that the goals and indicators PLC subordinated to objectives and indicators of superior systems (to post service and posts integrated logistics ).

**Table 1. Processes in PLC and the logistics performance indicators**

Identified processes	Qualitative performances	Financial performances	Time performances	Productivity performance
Taking over postal mails	<ul style="list-style-type: none"> <li>The degree of harmonization of documents and mails</li> </ul>	<ul style="list-style-type: none"> <li>The costs of unloading</li> <li>Cost of receipt</li> </ul>	<ul style="list-style-type: none"> <li>The time of receipt</li> </ul>	<ul style="list-style-type: none"> <li>The number of taken mails per personnel hour</li> </ul>
Classifying conclusions by type of shipments	<ul style="list-style-type: none"> <li>The accuracy of classification</li> </ul>	<ul style="list-style-type: none"> <li>Cost of classification</li> </ul>	<ul style="list-style-type: none"> <li>Classification time</li> </ul>	<ul style="list-style-type: none"> <li>Number of processed mails per personnel hour</li> </ul>
Transfer to a sorting area	<ul style="list-style-type: none"> <li>a) The degree of damage of shipments during the manipulation</li> </ul>	<ul style="list-style-type: none"> <li>The costs of transfer and manipulation of shipments</li> <li>Cost of shipments damage</li> <li>Cost of additional handling due to mistakes</li> </ul>	<ul style="list-style-type: none"> <li>Transfer time of shipments</li> </ul>	<ul style="list-style-type: none"> <li>The level of capacity utilization of transport and handling equipment</li> <li>The degree of time utilization of resources</li> </ul>
Sorting	<ul style="list-style-type: none"> <li>The number of incorrectly sorted shipments</li> </ul>	<ul style="list-style-type: none"> <li>Cost of sorting per shipment</li> <li>Additional costs due to mistakes</li> </ul>	<ul style="list-style-type: none"> <li>Sorting time</li> <li>Sorting time per shipment</li> </ul>	<ul style="list-style-type: none"> <li>The number sorted shipments per hour</li> <li>Achieved norm minutes per personnel hour</li> </ul>
Mails forming	<ul style="list-style-type: none"> <li>Accuracy formation of mails</li> </ul>	<ul style="list-style-type: none"> <li>Costs of forming the mails (resource utilization and raw materials costs)</li> </ul>	<ul style="list-style-type: none"> <li>Time for creating mails</li> </ul>	<ul style="list-style-type: none"> <li>The number of formed mails on hour</li> <li>The number of formed mails per personnel hour</li> <li>The number of formed mails per personnel hour</li> </ul>
Waiting for shipment	<ul style="list-style-type: none"> <li>The level of items that exceeded planned waiting time.</li> </ul>	<ul style="list-style-type: none"> <li>The costs of space</li> </ul>	<ul style="list-style-type: none"> <li>Waiting time</li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>
Transfer to the shipment zone	<ul style="list-style-type: none"> <li>The degree of damage of shipments during the manipulation</li> </ul>	<ul style="list-style-type: none"> <li>The costs of transfer and manipulation of shipments</li> <li>Cost of damaged shipments</li> <li>Additional handling costs due to mistakes</li> </ul>	<ul style="list-style-type: none"> <li>Transfer time of shipments</li> </ul>	<ul style="list-style-type: none"> <li>The level of capacity utilization of transport and handling equipment</li> <li>The degree of time utilization of resources</li> </ul>
Shipment (issuance of formed mails)	<ul style="list-style-type: none"> <li>The accuracy of document formation</li> </ul>	<ul style="list-style-type: none"> <li>Loading costs</li> </ul>	<ul style="list-style-type: none"> <li>Loading time</li> </ul>	<ul style="list-style-type: none"> <li>The number of submitted mails on personnel hour</li> </ul>
<b>Logistics performances of PLC</b>	<ul style="list-style-type: none"> <li>Degree of shipment damage</li> <li>The degree of shipments losses</li> <li>Degree of shipments delivered on time</li> </ul>	<ul style="list-style-type: none"> <li>The total logistics costs</li> <li>The total logistics cost per processed shipment</li> </ul>	<ul style="list-style-type: none"> <li>Process time</li> <li>Waiting time</li> </ul>	<ul style="list-style-type: none"> <li>The number of shipments processed per hour</li> <li>The number of shipments processed by personnel hour</li> </ul>

Some of these indicators are already present in the planning and manage the work in the PLC but not integrated into the logistics management system. Only by defining the structure of the process of logistics, establishing the relationship between the process and logistics performance with measurement systems of performance with, creating the basis for controlling logistics. The purpose of the internal

controlling of the PLC, the proposed list of indicators should be supplemented with: the use of indicators, the formula for calculating and the sources of collecting the necessary data. In this way preconditions are created the for the standardized collection of data, identification of performance, systematic comparison of their own performance.

## 6. CONCLUSION

Based on the structure of the processes which are implemented in the processing of postal shipments in the PLC with regard to the basic determinants of postal services, this paper proposed a list of logistics indicators as a base for the implementation of logistics controlling-in PLC. Proposed list of indicators should be accepted conditionally (selection procedure for logistics indicators is much more complicated) until PLC managers give their opinion about their importance and influence on the management of logistics processes during the realization of postal services. It is also one of the guidelines for future research in this area. In addition, the logistics indicators of PLC must be integrated into the system for logistics indicators of integrated postal service.

Despite mentioned limitations and bearing in mind existing practice in the Republic of Serbia, we hope that this study will be a little contribute to the improvement of logistics in the implementation in postal services.

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# SURVEY OF CUSTOMER SATISFACTION: THE EXAMPLE OF FREIGHT DISTRIBUTION CENTER

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**Abstract:** *Increasing of the strict market demands and complexity of logistics processes require a comprehensive survey of customers' views of the logistics services. Identification of customer's expectations, wishes and basic principles of the services, is the first step in establishing a model for continuous evaluation and monitoring of customer's satisfaction. This study presents a possible method of customers' satisfaction surveys in the case of logistics services provided by freight distribution center. The questionnaire, including analysis of obtained data, has provided insight in the realization of the customers' expectations and determined which performances of provided services are the most important. Knowledge of attitudes and requirements of the customer, has an impact on planning, realization and evaluation of effectiveness of the processes within distribution center. Surveys like this one are not just precondition for evaluation of the customer's satisfaction, they are also necessary for implementation of modern distribution center business concepts.*

**Keywords:** *freight distribution center, customer satisfaction, pilot survey.*

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## 1. INTRODUCTION

Any company that wants to maintain its ratings or to become a world market leader has to find new ways to strengthen its position. Large selection of quality products and their ratio of representation require that companies need to provide quality services that accompany the product and the realization of complete supply chain, in order to meet demands of the customer. Logistics has become an essential factor for a successful business because of wide spectrum of services which directly participate in defining the overall value of the product. Modern market trends are initiating and generating much stricter demands for quality of logistics services. The main aspiration of this logistics system is to fully meet the expected market demands in order to create satisfied and loyal customers, and thus provides a high market participation, competitiveness and long-term profits.

The company can fulfil these aspirations and objectives only if it provides complete and high-quality logistic services for its customers.

However, there is always a dilemma, what is a good quality logistics service or which attributes of service completely meet the requirements and expectations of customers? Continuous survey of users' views on services provided by logistic carriers

is the right way to determine the quality of given services. [2]

Management based on a good relationship with customers - CRM (Customer Relationship Management) becomes the key to all marketing processes of the modern company. Long-term linking with the customer in order to create long-term buyer/user cooperation allows changing of the basics of management philosophy that goes from products and businesses to a customer satisfaction.

This study highlights the importance of customer's satisfaction by measuring and it contains examples of original research of FDC (Freight Distribution Center) users' views. This pilot study was conducted in order to initially establish the basic performances of services which are essential from the user's perspective, as well as potential methods of continuous evaluation of customer's satisfaction.

A small scale survey is usually carried out prior to the main survey, primarily to gain information to improve the efficiency of the main survey.

## 2. MEASURING CUSTOMER SATISFACTION AS A FUNCTION OF QUALITY

Any Continuous measurement and evaluation of customer's satisfaction enables management to make strategic business decisions that contribute to loyalty of consumers. The choice of an adequate model for

the assessment and methodology for monitoring customer's satisfaction is of a great importance for this process. Satisfaction of users can be observed through many aspects, but here it will be presented only one that relates to the fulfillment of strategic goals of service provider who takes care of customers and improve service quality in accordance with their expectations/requirements. [7]

The concept that enables continuous improvement of operations of the company through customization is a CRM. [3] CRM for companies means to be well informed and be able to interact with profitable and potentially profitable customers, by considering their individual needs.

Managing relationships with customers/clients emphasizes the importance of a user-oriented business. The main goals of modern consumer relationship management are gaining new customers, deepening connection with existing customers and increasing of competitiveness and profitability. To achieve these goals it is necessary to personalize the communication channels and business transactions with each individual customer. Therefore CRM is much more than software support for automating marketing processes, it is a set of methods that increases the efficiency of these processes, more than sales or after market services and management. [1]

### **2.1 Survey of customer satisfaction**

Complete logistics service is the most important part of any logistics system where all processes and activities within logistics chain must be designed to support the required structure and level of logistics services. The goal of any logistics system is to provide complete logistic services which will fully satisfy the requirements and expectations of customers. [6]

In recent years, customer service becomes the primary weapon in the battle for survival on the market and overcoming competition.

All of this is due to the fact that the products are very similar, that they often have almost completely same characteristics, so the differentiation and competitiveness can be achieved in the field of logistics. [5]

All logistics quality surveys clearly show that there are no standards in this area, which could be successfully applied. In fact, there are a large number of measures such as that many of logistics managers give up on trying to measure and monitor quality. The complexity of this problem is shown by the fact that some universities of the world have formed a separate research teams whose projects are

dedicated to identifying the appropriate "set" of quality measures in logistics. [2]

## **3. DEFINITION OF SERVICE PERFORMANCE FROM THE USER PERSPECTIVE IN FUNCTION OF SERVICE SATISFACTION ASSESSMENT**

### **3.1 Freight distribution center GP Auto Shop**

Freight distribution center is a set of various functions and subsystems which enables realization of different processes and activities. The main task of FDC is to accept and offer effectively a wide range of products. FDC function is the reception, storage and dispatch of the entire assortment. Distribution center GP Auto Shop is a company which business activity covers a wide range of services. The main activity of the company is sale and distribution of tires for all types of vehicles, on the market that includes narrow administrative area of the city of Belgrade and greater Serbian regional centres. GP Auto Shop is the official distributor of tires for Michelin, Kleber, Tigar and Kormoran, which are part of Michelin Group. The main partners of the industrial and agricultural assortment are Michelin, Traya and Galaxy. In order to offer the best possible service to its clients, other goods are also included in its selling assortment, such as batteries (Black Horse, White Horse, Extra Start), motor oil (Mol, Shell, Esso, Mobil, Galax, Viskol, Selenia, Elf, Total, Modriča, Ina, BP), car cosmetics and car accessories (Auto Tec, Car Plan, Rally, Michelin Lifestyle), a specialized auto accessories (Thule, Concord), tools (Auto Tec, Takeda), service equipment and the company product line (windscreen liquid, distilled water, gas shock absorbers and fragrant air fresheners). Commercial distribution network in Serbia is associated with modern information system. The distribution network consists of the distribution-logistic center in Belgrade and stores with extra storage in Novi Sad and Niš.

They developed their own retail network with high-speed service in Lazarevac, Belgrade, Novi Sad, Subotica, Arandelovac and Kraljevo. The company possesses Renault and Dacia group automobile showroom in Lazarevac, built to the highest Renault standards.

GP Auto Shop customers are wholesale buyers, retail customers, supermarkets, gas stations and fleet customers. Wholesale customers are engaged in the sale and distribution, and retail customers at the same time are the end users and they do not distribute the goods any where further. Fleet customers are larger systems that have their own

vehicle fleet . Characteristic of fleet customers is that they know in advance the amount of tires they need, which has been confirmed in the contract. Supermarkets and gas stations have special requests on delivery of goods , which significantly influences their expectations from a FDC services.

The diversity of users and their requirements in relation to service, affected the interview process, starting from creation of the questionnaire, the research methodology, up to analysis of the results.

### 3.2. Analysis of the survey results in order to define performance of FDC services and customer satisfaction ratings

The survey was conducted on a random sample of 43 firms (53% of the firms are engaged in wholesale and 47% of them are engaged in retail sale) using a questionnaire with 34 questions, from August 2011 to October 2011. Interviews were carried out by GP Auto Shop company merchandisers. The obtained data were analyzed using SPSS 17.0 software. The results processing defines a customer profiles through the length of their existence in the market and based on the period of cooperation with the FDC. After that, demand for the product assortment was determined. Based on the amount of sold goods it was defined which goods has the most generators.

The frequency of requests for certain goods dictates the pace of operations and changes within the business orientation. It is important to know whether users harmonize their requests with FDC timetables, what their requirements are and whether they have any urgent shipments caused by sudden demands. The survey has obtained a lot of information which presents a picture of the functioning of FDC processes, and which may still be subject to analysis. For the purposes of this paper survey results which defines the performance of service are separated, which enables estimating - measuring of customer satisfaction.

### 3.3. The performance of service from a customer perspective

The customer assesses and evaluates the performance quality of logistics services in many different ways. Based on survey results, the following performances of service are relevant from the customer perspective:

- Delivery time.
- Delivery speed.
- The accuracy of delivery time.
- Proper condition of delivered goods.
- Courtesy of staff.

- Timely and accurate information which customers receive.
- The quality of delivered goods.
- Errors that occur during delivery of goods.
- Complaints to the errors and possible failures.

Delivery time is one of the most essential parts of logistics services. All activities that are necessary to be performed in order to prepare goods for delivery will be irrelevant if the goods are not delivered within specific time.

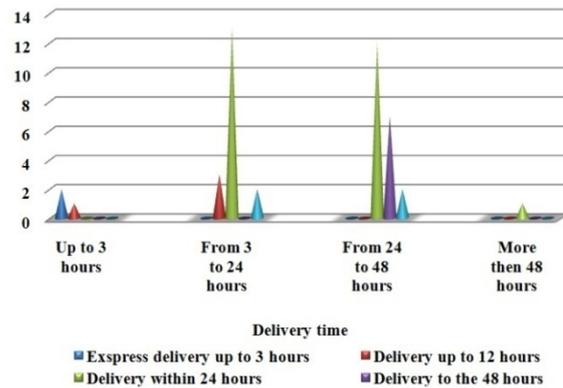


Figure 1. Relation between required delivery period and realization of achieved demands

If we observe the relationship of requested delivery period and time of its realization (Figure 1.), we can make a conclusion that the customers to whom goods are delivered within 3 hours have demanded such delivery. Within the realization of delivery for a period of 3 hours, there is a part of customer requirements to be carried out within 24 hours. Requirements that are realized in a shorter period of time prior to the defined time of delivery are causing customers positive attitude.

Ability to exceed customer expectations enables gaining and retention of the customer. Based on the survey results, we can say that the required delivery period is mostly harmonized with the time of its realization. Delivery speed is in accordance with the customer requirements. The vast majority of customers are satisfied with the realization speed of their demands, about 88% of them (Figure 2.)

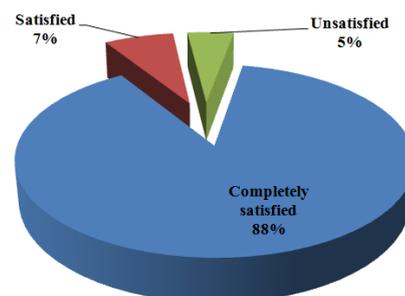
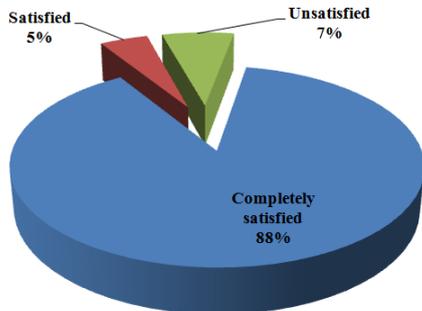


Figure 2. Customer satisfaction with the delivery speed

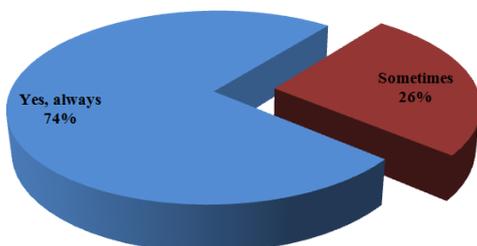
The accuracy of delivery time is another performance that affects the quality of logistics services, as well as the level of satisfaction of customer requirements. In this case, the percentage of fully satisfied customers is about 88%, with comments that FDC fulfils its promises in terms of accuracy of delivery time (Figure 3.).



**Figure 3. Measurement of the customer satisfaction with respect to the accuracy of the delivery time**

Besides fast delivery and exact time of delivery, condition of delivered goods is quite essential. From a customer's perspective it is extremely important that the products are delivered in proper condition. It is possible that the goods are not well protected during the delivery and to be damaged while transporting. It is necessary to determine the reasons for such cases, because the customer wants to get what he has arranged and paid for, otherwise he will not receive or accept the goods, and maybe next time he will choose to have another supplier. About 74% of FDC customers are satisfied with the condition of the delivered goods, while 26% of them have not received the goods in an acceptable state.

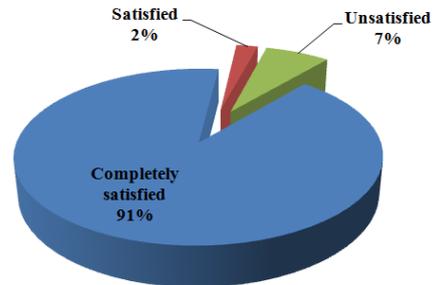
Even though the most customers are satisfied, we must not neglect the fact that more than a quarter of customers said that sometimes the goods were not in proper condition (Figure 4.).



**Figure 4. Satisfaction with the state of delivered goods**

Courtesy of staff is one of the preconditions for customer decision to choose the products and services of FDC. Constant training and educational programs introduced by FDC for its employees, policy that every customer is special and that his claims are priority, have a positive outcome.

About 91% of the customers are completely satisfied with the courtesy of the staff, 2% of them are satisfied, which leaves 7% of unsatisfied customers (Figure 5.).

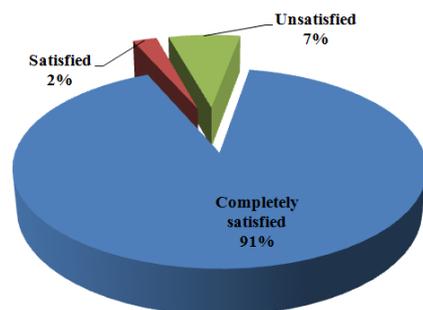


**Figure 5. Review of staff courtesy**

It is necessary to track the customers who are not satisfied with the services, in order to determine the causes and consequences of their dissatisfaction and whether they have a real reasons for it. There must always be striving for the best possible approach to to the customer, which allows the realization of good cooperation, gains the trust of the customers and the ability to establish a loyal customers. Previous experience of the company points out that the customer loyalty is crucial in terms of the information accuracy, which is very important from the aspect of the market developments. FDC forms business strategy based on such information. Providing timely and accurate information to the customer is important for maintenance and further development of business cooperation with FDC.

The customer need information about delivery of goods and whether a particular type of goods can be purchased. On the other hand, customers have their own competitors, so timeliness and accuracy of information plays a major role in the market.

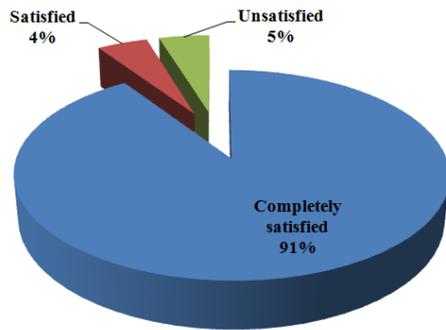
It is important that FDC provides accurate information for its customers in order to improve their business, gain and retain them as trusted clients. About 91% of the customers are completely satisfied with accuracy of the provided information, 2% of them are satisfied and 7% of them are unsatisfied customers (Figure 6.).



**Figure 6. Customers satisfaction with the timely information obtaining**

Considering the FDC product quality, there is a high degree of the customer satisfaction (Figure 7.). Besides the quality of the product, it is necessary that all the processes that accompany the delivery are realized in an efficient manner.

Customers loyalty can be achieved through the integration of the product quality and quality of logistics services. [4]

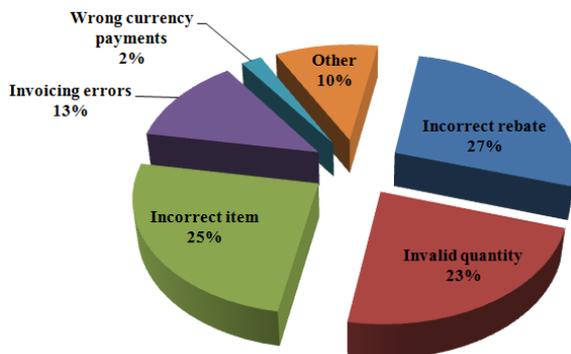


**Figure 7. Customers satisfaction with the FDC product quality**

The causes of errors that occur during the delivery of goods may be the human factor and the lack of control within the specified process.

For example, the error of the delivered goods quantity can happen because of a physical shortage of certain goods in the warehouse and its presence in the database. Adequate inventory management, increased control of the processes and the constant training of employees may lead to a reduction of the existing errors. Errors during the delivery are causing the customer complaints, so the regulation of factors that cause the errors can affect the reduction of those complaints.

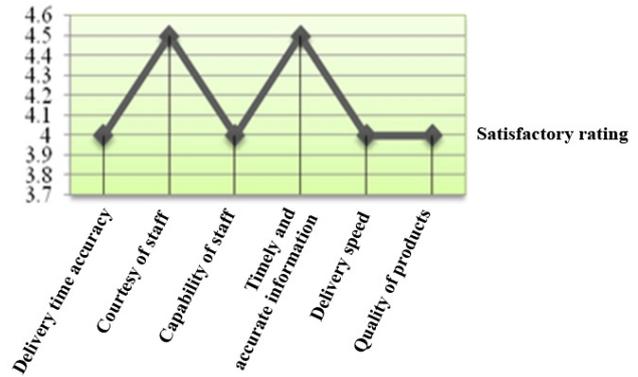
The survey shows that the most common errors that may occur during the delivery of goods are related to incorrect rebate, type of items, invalid quantity and invoicing errors (Figure 8.).



**Figure 8. Errors that may occur during the delivery of goods**

The results of this pilot study may be the basis for the implementation of tools that can continuously

measure satisfaction of customers with the services and also to improve or introduce new services in accordance with the assessment of customers. Evaluation of customer satisfaction with the performance of services shows the importance of the basic performance of services (Figure 9.).



**Figure 9. The importance of the basic performance of service**

Particularly useful results of such surveys are related to new services, and the possibility of innovation in accordance with expectations of the customers, which might be the subject of a special study.

This survey showed how customers are well-informed and interested in the use of B2B services, and also defines the benefits of B2B services over traditional ordering of goods, and after that FDC GP Auto Shop has started with the development of B2B services based on its modern information system.

#### 4. CONCLUSION

The example of logistics services provided by freight - distribution center GP Auto Shop shows how it is possible to monitor the satisfaction of customer requirements. Analysis of obtained results highlighted the performance of logistics services relevant from the customer's perspective. These performances have a direct influence on the attitudes of customers, and they demonstrate how the efficiency and effectiveness of the requirements realization affects the perception and experience caused by the provided service.

The customer assesses and evaluates certain quality performance of logistics services in a different ways. Level of customer requirements satisfaction directly depends on the value of logistics services performance. This reflects the importance of interaction between business systems and customers, as well as the active involvement of customers in the design and realization of services.

Constant monitoring of customers' satisfaction with the services or products, by measuring and assessing the level of satisfaction as a function of quality, is essential for the retention of the existing customers and gaining the new customers, in order to form and shape them in to a loyal customers.

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## THE PROBLEMS OF MEASURING EFFICIENCY IN LOGISTICS

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**Abstract:** *The efficiency is one of the key factors of company success. The importance of efficiency in logistics is recognized in literature and practice. In the efficiency measurement process different problems appear. Complexity and interdependence of logistics activities cause different problems like: indicator selection problem, conflicting goals, common resource problem, decomposition problem, etc. The mentioned problems are present on each measurement level: supply chain efficiency, logistics systems efficiency, logistics subsystem efficiency, logistics activity efficiency, etc. This paper gives the opportunities for overcoming mentioned problems. The proposed model is based on the Data Envelopment Analysis and the Principal Component Analysis methods. The case study results show that proposed model successfully overcome identified problems.*

**Keywords:** *Efficiency, Logistics systems, Distribution Centres, PCA – DEA.*

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### 1. INTRODUCTION

One of the most important engineering tasks is system design and process planning. Using different methods, techniques and knowledge engineers make variety of strategic, tactical and operational decisions. When the system is designed and the parameters are defined, it is necessary to quantify the operating effects (performances). Depending on industries and types of systems, there is a number of different performances. One of the basic and frequently used performances is efficiency. Efficiency is a very important indicator of companies' operations analysis.

There is no universal and generally accepted definition of the efficiency. Different authors define efficiency in different ways. The effectiveness is defined as the level of the goals accomplishment ("doing the right things"), while the efficiency represents the accomplishment of these goals in the best possible way ("doing the right things in the right way") [4]. In the past, both in the literature and in the practice, the greatest attention was paid to the operational efficiency.

The efficiency measurement process in manufacturing companies is completely different from the efficiency measurement process in the service companies. Raw materials and components in production process are transforming in final product. Tangibles and easy measurability of the

final product, and resource usage greatly facilitate the efficiency measurement of production processes. On the other hand the final product in the service companies is a realized service that is by its nature transient, intangible and quantity immeasurable, for which realization is often necessary to employ different measurable resources such as space, time, labor, etc.

Products of logistics companies, as well as the typical service companies are: transport services, warehouse services, material-handling services, freight forwarding services and other services. For their realization it is necessary to use various resources such as transport and material handling equipment, warehouse space, time, energy, labor, etc. whose usage is not easy measurable. An additional problem of measuring efficiency in logistics is the complexity, integration and mutual dependence of both resources involved, and realized services. When defining performances of logistics systems, it is possible to make very different and even conflicting aspects of performances. Defining and measuring the efficiency of logistics systems, as one of the most important performances in recent years is very significant. The existing models for measuring and monitoring efficiency are not fully applicable in the logistics and contain numerous constraints. The lack of models for measuring and monitoring the efficiency in logistics systems applicable in practice is evident. This confirms the lack of papers and models tested on the real

examples. The aforementioned problem and the importance of monitoring and measuring the efficiency of logistics services for practitioners and researchers are main motive of this paper. This paper provides an overview of problems for measuring the efficiency in logistics. The paper also gives opportunities for overcoming mentioned problems.

## 2. THE MAIN PROBLEMS

Measuring the efficiency of logistics systems and processes follows several groups of problems (Figure 1):

- Indicator selection;
- Efficiency measurement levels;
- Efficiency decomposition;
- Conflicting goals;
- Shared resources;
- Measuring efficiency of supply chains;

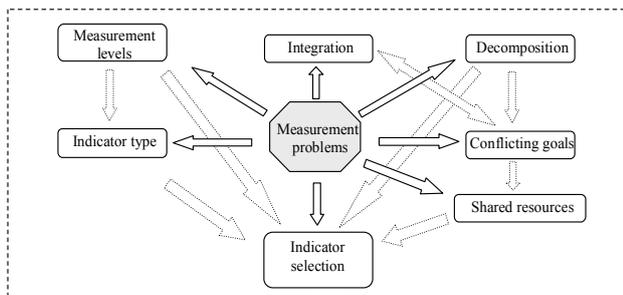


Figure 1. Efficiency measurement problems

Mentioned problems are the main problems in the efficiency measurement process of logistics systems. However, there are many additional problems that can not be predicted in the model development process.

### 2.2 Problem of measuring efficiency in the presence of multiple indicators

Logistics systems operating describe a large number of different indicators, and the problem is how to select relevant indicators which describe DC operating in the best way. The variables selection problem is recognized in literature [4]. Various indicators (operational, environmental, energy, qualitative, socio-economic, etc.) expressed in different units, related to different decision making levels (strategic, tactical, operational level) further complicate the indicator selection.

Under these conditions, the selection of indicators is problematic and critical process. In the real systems numerous indicators are monitored. Mentioned “single ratio” indicators give partial picture of logistics systems operating.

### 2.3 Efficiency decomposition problem

Efficiency decomposition is very important for logistics systems. In certain situation it is necessary to measure the efficiency of logistics subsystem, process and activity, not just system as whole. There is a lack of papers in literature that analyse this problem. The problem of shared resources and conflicting goals between logistics subsystems, processes and activities complicates efficiency decomposition [10]. The main task of the logistics system in terms of efficiency can be formulated as maximizing the overall efficiency of the logistics system and its subsystems, under conditions of shared resources and conflicting goals (Figure 2). However, each subsystem within the logistics system has its own strategy to achieve efficiency. The efficiency of one subsystem may be the result of the inefficiency of the other subsystem.

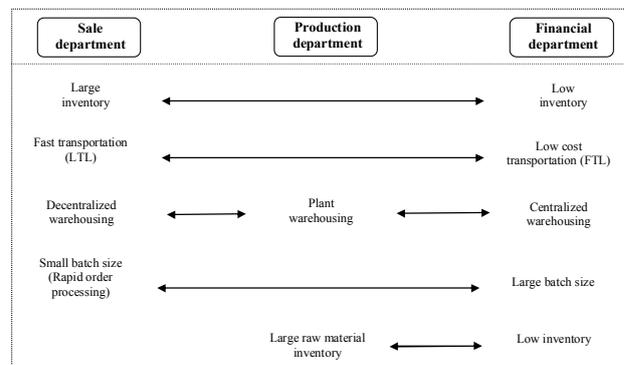


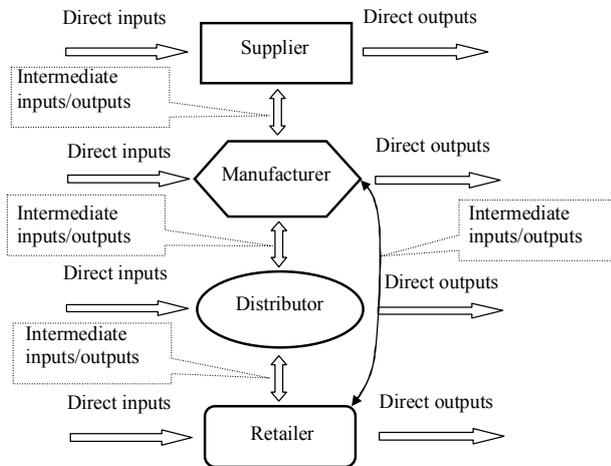
Figure 2. Conflicting goals of different sectors [10]

### 2.4 Problem of measuring supply chain efficiency

This problem relates to integration and influence of all participants in the supply chain. Each member in the supply chain is an independent actor with its own strategy to achieve efficiency. In general, the structure of the supply chain can be represented as in Figure 3. Some measures are associated with a specific supply chain member only. These measures are called the “direct” inputs and outputs. There are also “intermediate” inputs/outputs that link two members in the supply chain. For one member these measures represent inputs, while for another represent outputs.

Supply chain management requires the performance of overall supply chain rather than only the performance of the individual supply chain members. Sometimes, because of the possible conflicts between supply chain members, one member’s inefficiency may be caused by another’s efficient operations. For example, the supplier may increase its raw material price to increase its revenue and to achieve an efficient performance. This increased revenue means increased cost to the

manufacturer. Consequently, the manufacturer may become inefficient unless the manufacturer adjusts its current operating policy.



**Figure 3. Supply chain structure**

The integration of all supply chain members in the supply chain process represents a particular problem. In addition to suppliers, manufacturers, distributors and users sometimes appear as suppliers, customers of customers, distributor of distributors, etc. There are also companies that are members of several supply chains (for example, a glass manufacturer can be a supply chain member of several car manufacturers). For this reason, some authors advocate for measuring the efficiency of individual companies in the supply chain, which is essentially a simpler case.

### 3. EFFICIENCY OF LOGISTICS PROCESSES IS NOT MEASURED IN THE RIGHT WAY

Measuring the efficiency is a very important and difficult issue for each company. This problem is present both in the literature and in practice, regardless of the type and size of the company. According to conducted research about measuring and monitoring efficiency in real systems, certain conclusions are made. In distribution centres and other logistics systems, only "single ratio" indicators are monitored. Indicators like distance/driver, order picking transaction/order picker, warehouse and vehicle space utilization, etc. are known as partial productivity indicators and do not provide enough information about the company's operation. Many of them are included in others, which to some extent can lead to confusion.

The financial indicators are the most important for logistics managers. In that manner, great attention is paid to costs (fixed and variable), profit and turnover. The indicators are always observed independently without establishing the relationship

with other indicators and parameters. Besides financial indicators, operational (distance, shipped pallets, number of deliveries) and utilisation indicators (warehouse and vehicle space utilization, vehicle time utilisation) are also monitored. Efficiency is identified as partial productivity. In that manner, efficiency of a vehicle is defined as the relation between distance driven and fuel consumption, while order picker efficiency is the relation between number of order picker transactions per day. The mentioned indicators do not provide a real picture about vehicle efficiency or order picker efficiency, because they do not take into account all the parameters. It is also not good to make decisions based on mentioned parameters. For calculation of mentioned efficiency indicators and single ratio indicators, simple mathematical operations of multiplication and division are used. On the basis of the above findings, the review of reports and interviews with managers and other employees, it may be concluded that efficiency is not monitored or is not monitored in the right way.

On the other hand, the situation in the literature is not much better. The most of the models proposed in the literature can not be applied on real logistics systems. Almost all models are based on the DEA (*Data Envelopment Analysis*) method. This method has several disadvantages and it is not applicable in all situations. Among others, the discriminatory power of the DEA method decreases when the number of indicators increases. Models in literature are theoretically developed, and often inapplicable on real problems. This paper shows how to overcome mentioned problems on real case studies.

### 4. MEASURING EFFICIENCY OF DISTRIBUTION CENTRES IN THE PRESENCE OF NUMEROUS INDICATORS

The problem of measuring the efficiency of logistics systems in the presence of numerous indicators is recognized in literature. All approaches in literature solve this problem by selecting several representative indicators. The selection process is realized according to decision maker opinion. However, in this way, valuable information may be lost. In [2], authors propose a new approach for measuring the efficiency of logistics systems in the presence of numerous indicators. Unlike other approaches where variables are selected, this approach from a large number of indicators makes several artificial variables with a minimal loss of information. The variables from the first stage are then used for efficiency evaluation. The proposed

approach also gives opportunities for investigation the influence of all indicators in efficiency scores.

**4.1 Problem of measuring DCs efficiency**

The authors analyze the efficiency of the seven distribution centres in Serbia. Data has been aggregated for the twelve months of 2011. Each DC in each month is a separate decision making unit. Thus, a set of 84 DMUs is observed. The company management has used a variety of the “single ratio” indicators to monitor the operating of the DCs. As mentioned before this indicators do not provide enough information about the company's operation. According to various criteria, the indicators in logistics can be classified in different ways. In the observed case authors classify indicators into five groups as shown in Table 1. Input and output category is indicated in the third column. The warehouse and transport indicators are marked in the fourth column. Equipment and capacity indicators include general indicators frequently used in literature [7]. The largest group is the operational indicators group. Similar indicators are used in the literature ([3]; [9]). There are also "single ratio" indicators that observed DCs monitor, and to the best of authors' knowledge have not been used in the literature. Drivers overtime per driver and order picking transactions per order picker are some of them. Energy indicators are very important for logistics systems. Energy consumption costs in the DCs have a great share of total costs. Utilization factors greatly influence the operating of the company, on total costs, as well as on efficiency [11]. Apart from the warehouse and vehicle space utilization this paper also analyses time utilization of truck in the distribution process.

Failures in the transport and warehouse subsystems represent quality indicators which may be the cause of dissatisfaction and complaints of the customer. According [2] failures in the warehouse relates to the mistakes in the order picking process (shortage/excess in the delivery, articles mix-up, damages), but also to other processes such as bad inventory management, etc. Failures in the transport primarily concern the delivery that is falling behind schedule, as well as the damaging and losing goods in the transport process.

**Table 1. Indicators for DC's efficiency measuring**

Type	Variables	I/O <sup>a</sup>	W/T <sup>b</sup>
Equipment and capacity indicators	Vehicles	I	T
	Forklifts	I	W
	Employees in warehouse	I	W
	Employees in transport	I	T
	Warehouse area	I	W
	Pallet places	I	W
Energy	Fuel	I	T
	Electricity consumption	I	W
	Other energy costs (water, gas)	I	W
	Utility costs	I	W
Operational	Invoices (Demands)	I	W-T
	Warehouse overtime	I	W
	Driver's overtime	I	T
	Vehicle maintenance	I	T
	Driver's overtime/driver	I	T
	Shipped pallets	O	T
	Distance	O	T
	Deliveries	O	W-T
	Order picking transactions	O	W
	Tour/driver	O	T
	Delivery/driver	O	T
	Tons/ driver	O	T
	Pallets/driver	O	T
	Distance/driver	O	T
Order picking trans./order picker	O	W	
Turnover	O	W-T	
Utilisation	Time truck utilisation	O	T
	Space truck utilisation	O	T
	Warehouse space utilisation	O	W
Quality	Failures in warehouse	O	W
	Failures in transport	O	T
	Write off expired goods	O	W
	Total failures	O	W-T

<sup>a</sup> I-Input; O-Output; <sup>b</sup> W-Warehouse indicator; T-Transport indicator

**4.2 Model definition**

The proposed methodology is realized in two phases. In the first phase, it is necessary to implement the PCA for each of the groups of inputs and outputs separately. The PCs from the first stage are used as inputs and outputs in the second phase. PCA-DEA models are used in the second phase for efficiency evaluation. The model has the following form:

$$\min_{U_{PC}, V_{PC}} V_{PC} X_{PC}^a - v^a \tag{1}$$

$$V_{PC} X_{PC} - U_{PC} Y_{PC} - v^a \geq 0 \tag{2}$$

$$U_{PC} Y_{PC}^a = 1 \tag{3}$$

$$V_{PC_1^{equipm}} - V_{PC_2^{equipm}} \geq 0 \tag{4}$$

$$V_{PC_3^{energy}} - V_{PC_4^{energy}} \geq 0 \tag{5}$$

$$V_{PC_5^{operat}} - V_{PC_6^{operat}} \geq 0 \tag{6}$$

$$V_{PC_6^{operat}} - V_{PC_7^{operat}} \geq 0 \quad (7)$$

$$U_{PC_1^{utilisat}} - U_{PC_2^{utilisat}} \geq 0 \quad (8)$$

$$U_{PC_3^{quality}} - U_{PC_4^{quality}} \geq 0 \quad (9)$$

$$U_{PC_4^{quality}} - U_{PC_1^{utilisat}} \geq 0 \quad (10)$$

$$U_{PC_4^{quality}} - U_{PC_3^{operat}} \geq 0 \quad (11)$$

$$U_{PC_4^{quality}} - U_{PC_1^{utilisat}} \geq 0 \quad (12)$$

$$U_{PC_4^{quality}} - U_{PC_3^{operat}} \geq 0 \quad (13)$$

$$V_{PC} \geq 0 \quad U_{PC} \geq 0, \quad v^a \text{ free} \quad (14)$$

In the previous model  $V_{PC_1^{equipm}}$  and  $V_{PC_2^{equipm}}$  represent weights assign to the the PCs from the group of equipment and capacity inputs,  $V_{PC_3^{energy}}$  and  $V_{PC_4^{energy}}$  the PCs from energy inputs group,  $V_{PC_5^{operat}}$  and  $V_{PC_6^{operat}}$  from the operational inputs group. Similar,  $U_{PC_1^{utilisat}}$  and  $U_{PC_2^{utilisat}}$  are weights assigned to the PCs of utilisation indicators group,  $U_{PC_3^{quality}}$  and  $U_{PC_4^{quality}}$  the PCs from quality output group,  $U_{PC_5^{operat}}$  and  $U_{PC_6^{operat}}$  the PCs from operational output group.

### 4.3 Case study results

The first phase of the efficiency measuring is the PCA for all groups of inputs and outputs separately. From each of six groups main components were selected. All extracted components explain minimum 80% of total variance of each group (Table 2). Two PCs are extracted from equipment and capacity input indicators. They explain a vast of the majority of the variance in the original data matrices, since they explain more than 90%.

From the group of energy indicators two PCs are also extracted. In the first PC which explains 55% of total variance electricity and fuel consumption has the greatest influence, while in the second PC other energy costs have the greatest influence. Three operational input PCs explain 87% of variance.

On the output side six PCs are extracted. The first relates to utilisation factors in transport (time and space truck utilisation), while the second relates to warehouse space utilisation. In the quality output group two PCs are dominant. The first quality output PC incorporates failures in the warehouse and transport, as well as total failures, while the second incorporates write off expired goods. In the last output group two PCs are extracted. The shipped pallets, distance driven and turnover are largely correlated with the first PC. The warehouse

indicators (order picking transactions and order picking transactions/order picker) are dominant in the second PCs of mention group.

**Table 2. PCA scores (Correlation between variables and PCs)**

Inputs	Average	St. dev.	PC 1	PC 2	PC 3
Vehicles (No)	22.38	8.11	0.901	-0.390	
Forklifts (No)	51.76	25.18	0.950	0.047	
Employees in warehouse (No)	71.35	31.84	0.859	-0.468	
Employees in transport (No)	46.51	21.74	0.984	-0.070	
Warehouse area (m <sup>2</sup> )	8173.62	3311.03	0.737	0.501	
Pallet places (No)	4484.86	1947.72	0.699	0.584	
<i>Variance explained</i>			74.19%	90.34%	
Fuel (10 <sup>3</sup> m.u.)	2528.43	1673.49	0.849	-0.026	
Electricity consumption (10 <sup>3</sup> m.u.)	481.89	281.53	0.945	0.061	
Utility costs (10 <sup>3</sup> m.u.)	125.36	249.10	0.689	-0.487	
Other energy costs (water, gas, etc) (10 <sup>3</sup> m.u.)	167.76	157.78	0.335	0.897	
<i>Variance explained</i>			55.02%	81.17%	
Invoices (Demands) (10 <sup>3</sup> )	8505.01	2896.76	0.833	-0.355	0.142
Warehouse overtime (h)	373.33	445.21	0.375	-0.660	-0.630
Driver's overtime (h)	450.20	242.33	0.683	0.524	-0.282
Vehicle maintenance (10 <sup>3</sup> m.u.)	649.08	431.42	0.747	-0.290	0.508
Driver's overtime/driver (h/driver)	13.82	8.49	0.627	0.641	-0.110
<i>Variance explained</i>			45.05%	71.67%	87.02%
<b>Outputs</b>					
Time truck utilisation (%)	34.38	7.32	0.919	-0.020	
Space truck utilisation (%)	66.77	15.60	0.847	-0.389	
Warehouse space utilisation (%)	89.68	13.06	0.381	0.913	
<i>Variance explained</i>			56.86%	89.71%	
Failures in warehouse (10 <sup>3</sup> m.u.)	48.51	46.80	0.836	-0.336	
Failures in transport (10 <sup>3</sup> m.u.)	174.74	250.89	0.829	-0.185	
Write off expired goods (10 <sup>3</sup> m.u.)	45.85	68.91	0.601	0.794	
Total failures (10 <sup>3</sup> m.u.)	480.17	894.63	0.969	-0.045	
<i>Variance explained</i>			67.16%	86.67%	
Shipped pallets (No)	9021.48	4534.55	0.992	-0.088	
Distance (10 <sup>3</sup> km)	116.01	68.03	0.954	-0.188	
Deliveries (No)	4270.15	1751.67	0.759	0.435	
Order picking transactions (10 <sup>3</sup> )	188.29	98.94	-0.042	0.913	
Turnover (10 <sup>6</sup> m.u.)	281.06	178.81	0.955	0.023	
Tour/driver (No/driver)	27.36	13.64	0.909	-0.084	
Delivery/driver (No/driver)	112.52	28.06	0.764	0.314	
Tons/ driver (t/driver)	96.94	60.43	0.982	-0.092	
Pallets/driver	214.80	107.97	0.992	-0.088	
Distance/driver (km/driver)	2762.20	1619.86	0.954	-0.188	
Order picking trans./order picker (No/order picker)	6737.95	999.54	0.166	0.888	
<i>Variance explained</i>			69.83%	88.14%	

The second phase of efficiency measurement process is the PCA-DEA model for evaluating efficiency. The classical DEA models can not be

applied in this case. They do not have sufficient discriminatory power, considering the fact that almost 99% of DMUs are efficient.

There are numerous quality indicators in logistics. The ultimate goal, however, is customer satisfaction. No matter what indicator is concerned the quality of service greatly affects customer satisfaction. Satisfied and loyal customers mean a secure income for the company. On the other side unsatisfied customers and customer's complaints create additional costs. In this paper, more attention is paid to the failures in the distribution process. The author's assumption that quality indicators are more relevant for the efficiency evaluation is confirmed. This model maximizes discrimination with minimal loss of information. In that manner the PCA-DEA approach is more appropriate for the efficiency evaluation. The proposed model make greater differentiation between DMUs. Only 21% of the all DMUs are efficient with the average efficiency score 0.82.

## 5. CONCLUSIONS

Measuring the efficiency in logistics follows number of problems. Problems are present both in the literature and in the practice. In literature, there is a lack of case studies that test the efficiency measurement models on real logistics systems. This fact indicates the insufficient amount of research in this area. This paper shows how to overcome efficiency measurement problems, and how theoretical model can be applied in practice. The model proposed in this paper corresponds to a real situation of the observed logistics systems. The model also combined information obtained from employees and approaches from literature. The proposed methodology represents support in the decision making process. The model proposed in this paper, with minor adjustments, can be used for measuring and improving the efficiency of providers, warehouses, suppliers, etc. The presented models are a good basis for development of the future models. In the future research, models should include environmental and other quality indicators.

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# THE SIX SIGMA DMAIC METHODOLOGY IN LOGISTICS

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**Abstract:** *Logistics is the base of modern business, providing competitive advantages for companies on the market. Six Sigma is a data driven approach that lead to fact-based decisions, a methodology centered on understanding and eliminating the negative effects of variation it the processes. Great positive effects can be reached by applying this concept to the logistics, leading to the satisfaction of the clients, eigher internal or external, and finally to the financial benefit. This paper proposes the primary method of Six Sigma Logistics- DMAIC (Define-Measure-Analyze-Improve-Control). It presents the improvement of internal logistical processes by applying Six Sigma tools. The result is reduction in the number of defects, a reduction of a route time variability, and the reduction of the mean route time.*

**Keywords:** *Logistics, Six Sigma, variability, DMAIC.*

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## 1. INTRODUCTION

Six Sigma is a highly disciplined method of data collection and treatment that makes use of statistical tool, and requires a significant involvement of senior management and a hierarchy of workers with the necessary training. In technical terms, Six Sigma signifies a defect level below 3.4 defects per million opportunities (DPMO), where sigma is the term used to represent the variation of a process around its mean (Linderman, 2003).

The concept of variation reduction is paramount to the logistician. Logistics is about managing inventory, and managing inventory is about managing variance. Safety or “buffer” stocks are inventories needed to hedge against unknowns (i.e., the variation from the norm). Safety stock is maintained because of variation in supplier quality, transportation reliability, manufacturing process capability, and customer demand patterns. If variation in the processes from supplier to customer can be understood and controlled, a reliance on the buffers will be dramatically reduced. Variances in inbound and outbound logistics and variances in production control lead to the production stoppage, losing customer loyalty and losing customers or to reserving the liquidity in inventory. The principal objective of the Six Sigma methodology consist of the reduction of the variability associated with products/processes. It can be implemented either to forward or reverse logistics.

The Goal of this document is defining the usage of Six Sigma DMAIC methodology in the field of

logistics. The document is divided in three sections. The Section 1 gives brief review of Six Sigma literature regarding definitions and the usage of its concepts, the Section 2 defines the DMAIC methodology, while the Section 3 presents the case study that concerns the usage of Six Sigma methodology.

## 2. LITERATURE REVIEW

The Six Sigma concept was first introduced by Motorola Company in the mid 1980s, built on the philosophy of Total Quality Management. Since its inception, thousands of organizations have become ‘Six Sigma companies’ and a number of variants on the original concept have been developed, often combining Six Sigma with ideas from other improvement approaches.

Dean and Bowen (1994) defined QM to include techniques and a set of principles and practices. The monetary aspect was then emphasised by Harry (1998), Hahn et al (1999), Montgomery (2001).

The need for a common definition of Six Sigma was first emphasized by Linderman et al (2003). The goal of less than 3.4 defects per million opportunities was suggested, but was not included in the definition because ‘Six Sigma advocates establishing goals based on customer requirements’.

A trend of diversification of research topics from primarily manufacturing focused to more general in nature (service-related) included an increasing academic participation and broader focus than solely on manufacturing.

Another trend of omitting the statistical texts and theory and simplifying standard statistical methods was presented by Hahn et al (2001). The Six Sigma became more like a practice than a core method, as defined by Sousa and Voss (2002).

The literature review allows emerging trends and issues in Six Sigma to be highlighted, enabling the future work to progress as Six Sigma continues to develop and evolve. It also opens up new opportunities to apply Six Sigma in the fields that are not widely explored before.

### 3. DMAIC METHODOLOGY

DMAIC is one of the key pillars of achieving Six Sigma. Put simply, DMAIC is a means to an end. It does not necessarily determine the end, but rather provides the roadmap. Developed by using the voice of the customer and voice of the business tools, DMAIC pursues the opportunities for improvement, recognized in strategic analyses.

In order to implement the methodology successfully a company must be aware of the importance of the success factors such as:

- top management commitment
- team training
- data system (the valid data should be fully considered in order to avoid garbage in/garbage out effect)
- standardised procedures (standards allow setting expectations and the assessment of the current processes)
- forming the right team
- bottom line focus
- team involvement
- change management (flexibility) etc.

The methodology includes as its phases Define, Measure, Analyze, Improve, and Control.

#### 3.1 Define

The Define phase consists of:

- Defining the problem by developing a “Problem Statement”
- Defining the goal by developing a “Goal Statement”
- Define process by developing maps of the process
- Defining the customer and their requirements

The Problem Statement should include defining the severity (it can consist of percentage of the time there are errors, the number of late orders per month,

etc.), defining the business impact and specific area (what department and what units are involved).

The Goal Statement should be a direct reflection of the Problem Statement. For example, if orders are 10% late, then the goal might be to cut that down to 5% late. This statement defines measurable, time-bound terms of exactly when the team and project will be considered successful.

Defining the process begins with a bird’s eye view of the process, also known as a high-level process map. The classic tool here is called a SIPOC which stands for Suppliers, Inputs, Process, Outputs and Customers.

The focus of each project is the customer of the process. Customers can be external to the organization or an internal component of the organization. During the Define phase, the team must contact customers to better understand their requirements of the process, or the “Voice of the Customer.”

#### 3.2. Measure

Precision in defining the problem should facilitate the measurement phase. In this phase the objective consists of measuring the actual performance of the process so as to define its actual state. Should a focal problem for a DMAIC project be “improved reliability in delivery”, transit time would serve as the primary measure. Not only the average transit time should be measured but also the variance around it. Common areas of measurement include cost, time, quality. The best measures will prove to be those that are: quantifiable, easily measured, robust, reliable, valid. The measures should be prioritized so it is clear to everyone which measures are most important. This phase should reduce a risk of measuring the wrong things or measuring the right things in the wrong way. Bad information is driving bad decision making. It is moreover necessary to establish the measurement system that allows the monitoring of the process evolution under analysis with respect to the objectives established in the previous phase. A well thought out data collection plan is critical as the data that is gathered must be accurate and reliable. The collected data is then incorporated into the Project Charter to more accurately describe the issue.

#### 3.3. Analyse

This phase has as its objective the identification of the causes that could be at the root of the problem and identify the relations of Cause- Effect, i.e., how is it that one of more independent variables affects the dependent variable. It includes identification of the issues that lead to dissatisfied customers,

unnecessary costs, dwindling margins, and frustration. In this phase the data collected during the Measure Phase is reviewed. An additional information can be included. The team analyses both the data and the process in an effort to narrow down and verify the root causes of waste and defects. The data is presented visually using charts and graphs for easier identification for problems in the process. The process analyse consist of:

- Time Analyses that focus on the actual time work is being done versus the time spent waiting
- Value Added Analysis that adds another dimension of discovery by looking at the process through the eyes of the customer to uncover the cost of doing business
- Value Stream Mapping combines process data with the map of the value-adding steps to help determine where Waste can be removed

Teams are able to develop theories around possible causes of the problem by brainstorming together. By using a tool called a “Cause & Effect Diagram“, the teams are able to perform structured brainstorming that can help them narrow down to the vital few causes of lost time, defects and waste in the process.

By using Design of experiments, the logistician might examine the variance in delivery reliability by controlling for different factors associated with shipments of interest including, but not limited to, the way in which shipment is tendered, dispatched, and scheduled; the way in which the order is physically prepared, staged, and loaded; the carriers and drivers used to fulfill the delivery; the time of day for pickup and delivery; weather conditions; and the processing of the documentation associated with the shipment. The Charter is then updated with additional detail around process performance and the potential for improvement.

### **3.4 Improve**

This phase has the objective of finding and implementing solutions that eliminate the causes of the problems identified in the Analyze phase, preventing a re-occurrence or reducing the variability of the process. Making effective change is not an easy thing for any organization. Lean Six Sigma thinking is about discipline, and about developing a culture that relishes opportunities for improvement. While there may exist various possible solutions for the same problem, the best, or top two should be selected to be applied. Ideally, these identified solutions should not imply such

large investment costs and they should be tested before being implemented such that their efficacy can be checked and to avoid wasting time on solutions that require a great deal of effort for little benefit. In order to ensure the right decision is made, the team may employ mini testing cycles known as “PDCA” or Plan Do Check Act, which can help refine the ideas while collecting valuable stakeholder feedback.

### **3.5 Control**

What can prove even more challenging than bringing a good idea to light in the Improve phase, is sustaining the effort. In Control phase the improvements implemented are controlled, or in other words, the new system. Actions should be defined so as to guarantee that the process is continuously monitored, so as to assure that the key variables maintain within specified limits. New standards and procedures should be defined, workers should be trained for new process and new measures should be defined to ensure the sustainability of the gains. This phase focus on avoiding complacency when the project is going well and goals are being met and taking corrective action when either the projects strays or the environment changes. This phase is a mini version of process management. The team has been building a form of infrastructure throughout the life of the project, and during the Control Phase they begin to document exactly how they want to pass that structure on to the employees who work within the process.

## **4. CASE STUDY**

Case study offers an effective way to comprehend the concept fully. Unfortunately logistics is such a broad function with diverse activities and it is virtually impossible to write a case that will satisfy all customers of the case. In the following case study will be presented the application of the DMAIC methodology to the internal logistics of a company that manufactures domestic water heating equipment, as fundamental to the success of the business. The consequences of not delivering the materials in the right quantity, at the right time and in the right place are lost production and missed delivery deadlines that influence the satisfaction of the client. Internal supply concept includes milk-runs, Point of Use Providers and logistical trains. The milk-runs are the operators that deliver all the materials located in the warehouse to the supermarkets of internal clients. The process starts with the requests from the operators responsible for the movement of the

materials from the supermarkets, close to the point of use, to the final point of use for replacement material. An electronic request is made using a barcode reader. These electronic requests are received by the warehouse operators who place the necessary material in the logistic train. The milk-run operator couples up the various carriages to form a train according to the defined route. After delivering all of the requests, the trains is returned to the warehouse, where the empty carriages are being uncoupled, filled ones carriages coupled and a new route is started.

There are three routes for the delivery of materials: A, B, C. A and B routes run cyclically, while C route does not. The duration of A and B routes is fixed at 30 minutes, while the C route is of less duration than other two. The A and B routes that run for more than 30 minutes are considered as a defect. The outcome can be a production stoppage. Also, the variability of the time of the routes leads to a necessity of having a safety stock in the supermarkets.

The objective of this project is to control the duration of the process of the internal restocking of materials.

The problem was defined. "Between January and February 2011, approximately 50% of the routes were found to have an execution time above the maximum allowed time, defined as 30 minutes. This delay in the delivery time negatively affects system confidence and increases the necessary safety stock in the supermarkets of the internal clients."

The objectives are defined in the Table 1.

**Table 1. Definition of the project objectives**

Objective	Jan.	Feb	Objective
Reduction of the DPMO	345.238	551.020	10.000
Increase in the sigma level	0,4	0	2,3
Reduction in the coefficient of variation (%)	44	36	11,5
Reduction in the average time (min)	27	34	25
Coupling/decoupling (min)	12	12	0

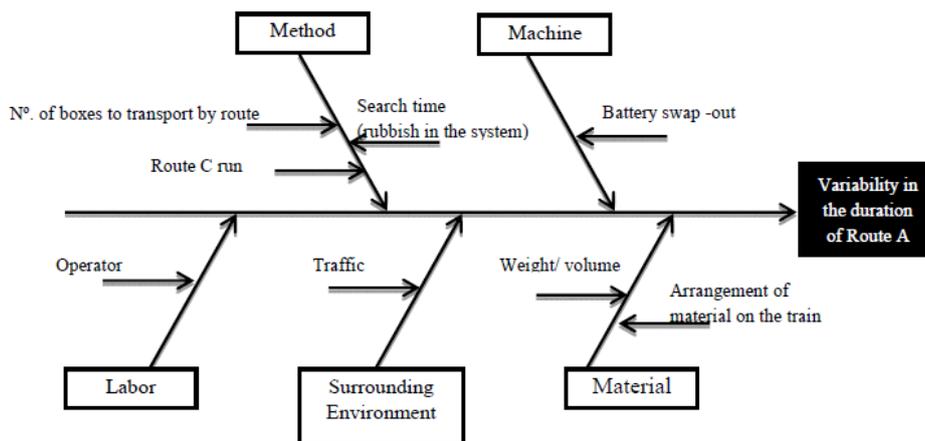
The expectations of the clients served by the route A were taken into a count when defining objectives. The workshops were organised with the Production managers.

The voice of the customer concept was used for a definition of client requirements. Their requirements were 0% of production stoppages due to stoppages, 50% reduction in stock safety margin in the supermarket, 0% of area occupied by the supermarkets-direct delivery to the point of use.

It was concluded that that the duration of the route A had an impact over the production stoppages due to parts stock out in the supermarkets and safety stock necessary in the same supermarkets.

In this case study the duration of the route A was measured. Of the 148 routes that were analyzed for the month of March 77 routes ran over the limit of 30 minutes, representing the defect level of 52%, or DPMO of 516.779 (sigma level of 0).

In an analyze phase a Cause-Effect diagram was developed for identification of the factors that can have an impact on the route time (Figure 1). A brainstorming session was organised.



**Figure 1. Cause-Effect diagram**

An inferential statistics was used to understand both the impact of route C on the running time of the route A and the impact of the cause of 'N of boxes to deliver by route'. By using the hypothesis it was concluded that there exist a significant difference in

the time taken to run route A when it is preceded by a run of route C. This happens because runs of route A that follow a run of route C have the tendency to include more boxes to be delivered. A Linear Regression Test was used for quantification of the

impact of the cause of 'Number of boxes to deliver by route' on the route time. The relationship between the independent variable 'Number of boxes loaded onto the logistic train' and the dependent variable 'Time necessary to run the route' was tested. It was concluded that the time taken to run route increases with the number of boxes to be delivered.

In the improve phase the solutions to the problem being studied were proposed by the project team. An evaluation of the impact and effort required is shown in the Table 2.

**Table 2. Evaluation of the Impact and Effort of the various solutions proposed**

Solutions	Impact	Effort	Observations
The milk-run covers only A	9	4	Allocate Route C to another operator
Delivery of a fixed number of boxes per route	8	7	Necessity for a 3 <sup>rd</sup> train
Relocate the heavy and outsized materials	3	4	Analyze in what location the heavy materials are to be found. Locate them as close as possible to the milk-run stop.
Eliminate the obsolete parameterizations from the information system	2	6	Analyze piece by piece the parameterizations in the system that are no longer used. Eliminate contradictory information.

It was decided to make a pilot test with the first two solutions according to their potential impact, as the solutions should be tested before their implementation, so that their effect is checked.

During the test period of 15 days for the solution 'Process Route A w/o C', of the 79 routes that were completed, 12 took longer than 30 minutes, showing the defect rate of 15%, or DPMO of 151899. The variability of the route running times was also reduced from 37% to 26%. There was no positive effect on the stopping time in the warehouse of 12 minutes used for decoupling and coupling operations.

The test of other solution was carried out but in combination with the 'Process Route A w/o C' solution. It resulted with only one of the 30 routes ran during the test period with the duration more than 30 minutes, representing a defect rate of 3%, or DPMO of 33333, representing sigma level of 1,83%. The variability of the route running times was also reduced from 26% to 14%. There was a negative effect on stopping time in the warehouse that rose

60%. The average time of running a route remained at 24 minutes.

In order to reduce stopping time in the warehouse it was decided to test the proposal 'Quick change of carriages' beside other two proposals.

The results obtained from the tests are shown in the Table 3.

**Table 3. Client requirements**

Objective	Jan.	Feb	Goal	Result	Status
Reduction of the DPMO	345238	551020	10000	33333	x
Increase in the sigma level	0,4	0	2,3	1,8	x
Reduction in the coefficient of variation (%)	44	36	11,5	14	x
Reduction in the average time (min)	27	34	25	24	✓
Coupling/decoupling (min)	12	12	0	0	✓

Even though some of the goals were not reached, an improvement was made in all of the performances.

As the waiting time for a complete load was long, the project team decided to make a new test with the new solution -'Single Route', resulting from an integration of routes A and B. Even though there was a slight degradation in the average time for the routes and in the variability of the time from 14% to 16%, and in number of routes taking more than 30 minutes (3 routes), a positive effect was found. The stopping time in the warehouse between two route runs reduced from an average value of 30 minutes to 6 minutes, as a full load was achieved more quickly thanks to more stations visited on the route.

For the purpose of control, the automatic card system for registering the time of exit and the time of entry to the warehouse was maintained. Three months after the go-live phase, 7 routes of the 190 were carried out in more than 30 minutes, representing a defect rate of 3,6%. The average duration of the routes run was 24,4 minutes. These results showed that the new process was stabilized.

The safety stock in the supermarkets was reduced, as a result of the improvements in the performances. An integration of two routes into a single route allowed the reduction of two operators per day, as the elimination of one traction device, rented from an external company. These reductions resulted the reduction in costs of around 100 000€ per year.

## 5. CONCLUSION

The variation reduction and reduction of defects are of big importance to the logistician as managing inventory, customer's trust and sale are about managing variance. Six Sigma is about understanding the origin of defects and variation and finding the solutions for eliminating them and getting as close as possible to 'Zero Defects'. It is a simple, effective, process-oriented and structured way of making improvements with a clear division of responsibility and goal to achieve significant results. It should be seen as a program for continual improvement over the long term. The DMAIC is the 'backbone' methodology applied in Six Sigma improvement efforts. Its implementation within the project described in this article brought a financial benefit to the company of around 100 000€ yearly.

This methodology is an excellent complement to the Lean methodology.

A focus on quality achieved through variation reduction can be a core element of a company's philosophy and strategy.

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**Part VI**

**SUPPLY CHAIN  
MANAGEMENT AND REVERSE  
LOGISTICS**

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## APPLYING LEAN THINKING TECHNIQUES IN THE AGRIFOOD SUPPLY CHAIN

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**Abstract:** *In this paper, a three-step approach for measuring the environmental performance of specific supply chains in agrifood sector based on the Value-Stream Mapping (VSM) technique is proposed and analyzed. The approach aims to determine waste, in terms of measuring the non value-added time of production and logistics processes, as well as, water and energy used across organizational boundaries. Furthermore, in order to demonstrate its applicability and effectiveness and to understand its sustainable impacts, the suggested approach is applied in an agrifood product (corn) and the corresponding supply chain. VSM diagrams are created and specific practices are proposed in order to minimize waste in the examined supply chain.*

**Keywords:** *Food Supply Chain, Corn for animal feed, Lean thinking, Green Supply Chain, Value Stream Mapping.*

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### 1. INTRODUCTION AND LITERATURE REVIEW

Lean thinking is an approach that has gained significant popularity over the last years due to its ability to identify and eliminate non-value adding but cost incurring activities. The approach has recorded significant successes resulting in a worldwide and across sectors recognition including both products and services.

The success of this approach was supported firmly by Womack and Jones (1996) through their illustration using a number of companies (case studies and best practices) that had deployed the approach and experienced the benefits in a significant way [18]. In their work the authors provided detailed analysis of how companies deployed lean principles to prevent the near collapse of a company. The conclusion drawn, however, was that five lean principles ought to be implemented for benefits to be realized. These included: 1. Definition of value from a customer's perspective, 2. Identification of the entire value stream and

eliminating waste, 3. Creation of the value stream, 4. Production in response to customer demand, and 5. Pursuit of perfection.

Overall, Lean thinking can be defined as a set of principles, techniques and tools all aimed at minimizing non-value adding processes which are characterized by wastes of different forms. According to Emiliani and Stec (2004) these were classified as the seven wastes of a business process and included the following: Overproduction, Waiting, Transportation, Processing, Inventories: raw material, work-in-process, and finished goods, Moving: both operator and machine, and Defects: defective products or process outputs [5], [6], [8].

Some of the techniques used are: Takt Time, Kaizen, Statistical Process Control, Poka-Yoke, 5S, Value Stream Mapping (VSM), Total Quality Management, Kanban, and Jidoka, among many others. Plenert (2007) and Abdulmalek and Rajgopal (2007), emphasizes especially the significance and usefulness of the VSM as a key tool of Lean thinking [10], [1]. A VSM helps on identifying opportunities for lean improvement by spotting activities that are not add value to the process. VSM

is a visual representation of processes within a pathway and can be considered as a visual map of all the activities, illustrating how they linked to each other, and information such as timing and resources. It aims identifying all the value-add and non-value-add (waste) activities, as an opportunity to remove non-value-add steps and eliminate waste through problem solving, to standardize and improve value-added processes but mainly to eliminate waste. It has four stages, beginning with preparation, current map, future map, and finally, an improvement plan.

On the other hand, there are business sectors and their corresponding supply chain networks that the application of Lean thinking techniques seems to be very promising. In this paper, the study is focused on the agrifood sector. This sector is characterized by real constraints on natural resources, as well as, high production costs, higher risks, and competition for resources by the producers [2], [3], [11]. There is a high need for decreasing the lead time due to the nature of the products and this decrease could easily translate to lower financial costs and lower inventory management cost. Moreover, there is also the “consumers’ awareness need” who (customers) are better informed and better educated in terms food quality, food safety and food nutrition issues.

In the literature there are many researches that concentrated to the application of Lean thinking for greening the supply chains [4], [13], [15], [17]. As Womack and Jones (1996) wrote: “*Lean thinking must be “green” because it reduces the amount of energy and wasted by-products required to produce a given product*” [18]. Simpson and Power, (2005) investigate the relationship between supply relationship, lean manufacturing, and environmental management practices proposing a conceptual framework to depict this relationship [14]. Yang et al. (2010) also explored the relationships between lean manufacturing practices, environmental management, and business performance outcomes [19]. All the above studies justify what Florida (1996), King and Lenox (2001), and Rothenberg et al. (2001) argue that “when using lean principles to achieve environmental production, it will bring also considerable cost benefits besides green production since Lean thinking has common goals with environmental production” [7], [9], [12].

In the recent years a number of researches have focused on the application of Value Stream Mapping for supporting the greening efforts. A great work has been done by the United States Environmental Protection Agency (USEPA) when at 2007 first introduced the Environmental Value Stream Mapping (EVSM) method, which has all the characteristics of its parent -Value Stream Mapping-

but additionally environmental issues and the usage of material or energy. Another organization in US; the USA Environmental Protection Agency (or EPA), at 2007 proposed the Energy Value Stream Mapping (EnVsm) as a tool which has the information and data about energy usage of each process item as well as its regular lean data in the typical format (VSM). The aim of the above tool is to have both data from the value added action and process beside the energy usage or waste in a same picture so to give this opportunity to the analyzer team to improve the future state of the process in a way that has better and more efficiency in both ways; lean principle and energy saving [6].

Based on the above studies and initiatives this paper explores the application of the VSM tool in the typical format so as to determine the waste in a specific agrifood supply chain of the corn product for animal food. Therefore, the main objective of this paper is to propose a systematic approach for measuring the environmental performance of supply chains in food sector based on Lean thinking techniques so as to identify sources of waste in the selected supply chain. Specifically, VSM is suggested for determining waste, in terms of measuring the water, energy and lead time of the production process.

## 2. CASE STUDY

In this section the Value Stream Mapping (VSM) tool is used in order to develop a visual representation of existing operations (Current State Map, CSM), so as to identify the largest sources of waste (non-value added activity) in the value stream of the corn supply chain and especially the production process of animal food products, as well as, to develop an implementation plan for lean techniques (Future State Map, FSM). The examined company is one of the biggest feed companies in Northern Greece. It produces compound feeds for poultry, rabbits, cattle, sheep & goat, pigs, horses, pets, etc. Two interviews were arranged with the Production Manager and Operations Manager in order to apply in practice the following three-step approach.

Step 1: Selection of agrifood supply chain processes to be value-streamed. A typical production process after the harvest of the corn and its supply either from the national or global market is executed as follows. Corn comes either from farmers or suppliers (both in domestic or foreign market). First, corn drying is a necessary post-harvest process that prevents the growth of microorganisms and deterioration of the product (for prolonged storage, a

moisture content of less than 14% is recommended). The energy consumption for corn drying varies due to the variability in corn's moisture content, which usually ranges from 16-22%. The required energy to reduce moisture content of corn from an initial value of 22% to the desired 14% is estimated to be around 520 BTU/t [16]. Due to the short harvesting period, industries that produce animal feeds on a large commercial scale are forced to store large amounts of dried corn in specifically designed silos with a capacity of a few thousand tons (usually around 2000 tons). In order to preserve quality, it is necessary to aerate frequently the silos with high power electric blowers. The feed mills are also forced to transfer previously stored cereals from one silo to another, which aims at preventing temperature rise. It is difficult to predict the energy requirements for such processes because these depend on both storage time and corn quality. Besides the aforementioned preservation methods, common practice is the addition of preservatives (e.g. ammonium propionate) at concentrations of 2-3%. Due to the limited financial fluidity, feed mills do not proceed to the storage of large amounts of corn during the harvesting season; rather they procure the necessary amounts from either domestic wholesale or directly via imports.

The production of animal feed mixture follows. Well-organized feed mills produce various types of animal feeds for feeding all kinds of livestock. The amount of corn added to the different types of animal feeds varies between 10-70%. For the production of a typical mixture of animal feed for chicken fattening (broilers-final stage), the amount of corn added is up to 60%. In this mixture, various proteinaceous ingredients are added (soy bean meal, fish meal), lipids, inorganic nutrients (calcium, phosphorus, magnesium, salt, minerals) as well as a multi-vitamin mix.

The production process includes the following stages: weighing, grinding, mixing, pelletizing, and packaging in bags or bulk transportation to the fattening units with silo vehicles. Energy consumption for the production of palletized animal feeds is at an average 85kWh/ton (according to the Advisory Committee on Animal Feeding stuffs - ACAF/ 53rd Meeting on 2 March 2011). Water consumption, in the form of steam, during the production process ranges from 40-60 kg/ton of product. According to these values, the energy consumption for corn solely, as part of a chicken feed mixture is  $85 \text{ kWh} \times 60\% = 51 \text{ kWh/ton}$  final product. The respective amount of water accounts for 24 to 36 kg/ton of final product. Gas emissions to the environment are limited to the amounts

necessary for the combustion of gas/oil for the production of steam, mentioned above. No liquid wastes are formed during the production of animal feeds, while solid wastes, in the form of dust, are easily held by filter bags and are not considered an environmental hazard.

In order to identify the corn supply chain processes to be value-streamed we use the following criteria: 1) processes with high energy, water, material and hazardous material use, 2) processes with significant solid or hazardous waste generation, 3) processes requiring environmental permits or reporting to environmental agencies, and 4) processes that include special pollution control equipment. Based on the proposed four criteria we asked the two managers to evaluate the significance of the processes that emerged from the production procedure in the examined case. Managers took into account the effects, causes and environmental impact of the seven wastes as depicted in Table 2 and evaluated the processes using four values: Not significant, Low, Medium and High (significance).

The following table presents and evaluates the processes that were identified with the above criteria based on the responses of the Production and Operation managers (Table 1).

**Table 1. Identifying the corn supply chain processes to be value-streamed**

Criteria \ Process	High energy, water, material and hazardous material use	Significant solid or hazardous waste generation	Environmental permits or reporting to agencies	Special pollution control equipment need
Drying	High	Medium	Low	Low
Storage	Low	Not significant	Low	Low
Weighing	Low	Not significant	Not significant	Not significant
Grinding	High	High	Low	High
Mixing	Medium	Low	Low	Low
Pelletizing	High	Low	High	High
Packaging	Low	Not significant	Medium	Medium

According to the above findings all the processes were selected for the development of current and future stream maps (Step 2 and 3).

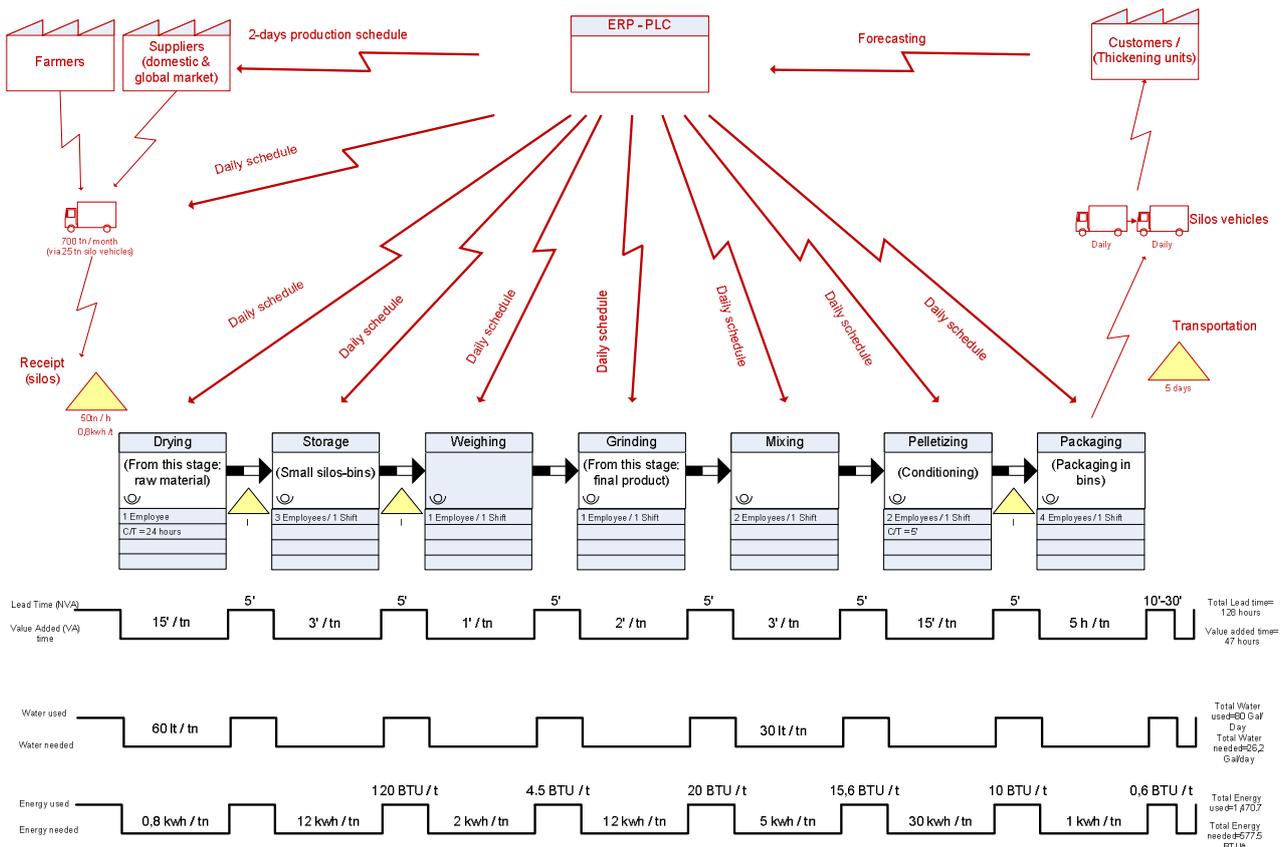
**Step 2: Development of the Current State Map (CSM) of the selected logistics processes in the agrifood supply chain.** In order to develop the CSM of the corn supply chain, a number of calculations were made in every process of the animal feed production that was identified in the previous step. The study was focused on the environmental aspects of the targeted procedure and was referred to liters of water and energy used as depicted in the following table.

**Table 2. Estimating water and energy used**

	Water used (lt /tn)	Energy used (kWh / tn)
Drying	50	0.8
Storage	-	12
Weighting	-	2
Grinding	-	12
Mixing	-	5
Pelletizing	30	30
Packaging	-	2

According to the estimations some processes that were measured have some of the environmental impacts that were presented in the Table 2 but all have time and labor inputs such as the number of employees / shifts, cycle time (c/t), operation time (o/t), set up time, scrap rate, rework rate, etc. Figure 1 presents the Current State Map. In the bottom of the map there are three lines that represent: 1) Total lead time and value added time, 2) Amount (liters) of water used (top line) and amount (liters) of water needed (bottom line) per day and per process, 3) kWh's of energy used (top line) and kWh's of energy needed (bottom line) per day and per

process: for measuring energy consumption a power measuring device (the power consumption of a machine for machining a part or a batch over a particular time in 24 hours) and a data logger were used. Since the examined production process is fully automated and especially from Storage to Packaging, Total Lead Time and Valued Added Time are not considerably different. Therefore, and based to Table 2, Inventory, Transportation and motion waste, as well as, the Waiting waste are not critical. Furthermore, according to the historical data maintained by the Quality Control company's department, the Defect level (caused by scrap rate, design error, machine setup, wrong process production and quality protocol assessment) is very low (~0.5% per lot) so this waste is also not critical. In contrast, there are two processes that have significant environmental impact in terms of water and energy used: Drying and Pelletizing. Moreover, three wastes according to Table 2 (Over-production and Process), have been selected for a more detailed examination.



**Figure 1. Current State Map**

**Step 3: Development of the Future State Map.** The main objective of this step is the identification of processes with main environmental, health, and safety opportunities on the CSM. But most of all, this step includes the identification of the

appropriate, practices, technologies and tools in order to minimize waste. According to the findings of the previous step, authors and the two managers of the manufacturer have focused on two wastes:

Over-production and Process, and two processes: Drying and Pelletizing.

Based on the above, three practices were proposed. First, more accurate forecasting procedures based on mathematical models and by exploiting the historical sales and production data can confront effectively with the over-production. Furthermore, the use of the takt time, based on the available working time of the downstream processes that are closest to the customer and specifically from Storage to Packaging will surely guide the production rate with the rate of sales, to meet customer requirements.

Second, animal feed production units refer to either neighboring to the plant areas and sometimes in areas that are a few hundred or even a few thousand kilometers away. As a result, the capabilities of animal feed production units for developing long-term planning strategies, regarding the supply of corn, are limited. The composition of animal feeds can be automatically formulated by specifically designed software, in order to satisfy the nutritional needs of both terrestrial animal and avian

species with the least cost formulation. For instance, if the price of wheat is rising with respect to corn, then the ratio of wheat added into a product may decrease and be replaced by corn. Third, cultivation of new types of corn hybrids has gained much interest over the last few years.

These new types of corn hybrids can be naturally dried in the field (which is favored by the climate conditions in Greece), practically, without using dryers. This allows the supply of corn during the harvesting period, with an estimated moisture content of 14-15% (w/w), which is within the acceptable limits. Furthermore, it is possible to mix corn batches from different suppliers without classifying the batches into low- and high-moisture. Elapsed time for discharging 25 ton of corn in a medium-sized plant is about 30 minutes. Common practice does not require truck arrival at specific times.

Figure 2 shows the Future State Map (FSM) created for the examined production process based on the recommendations previously mentioned.

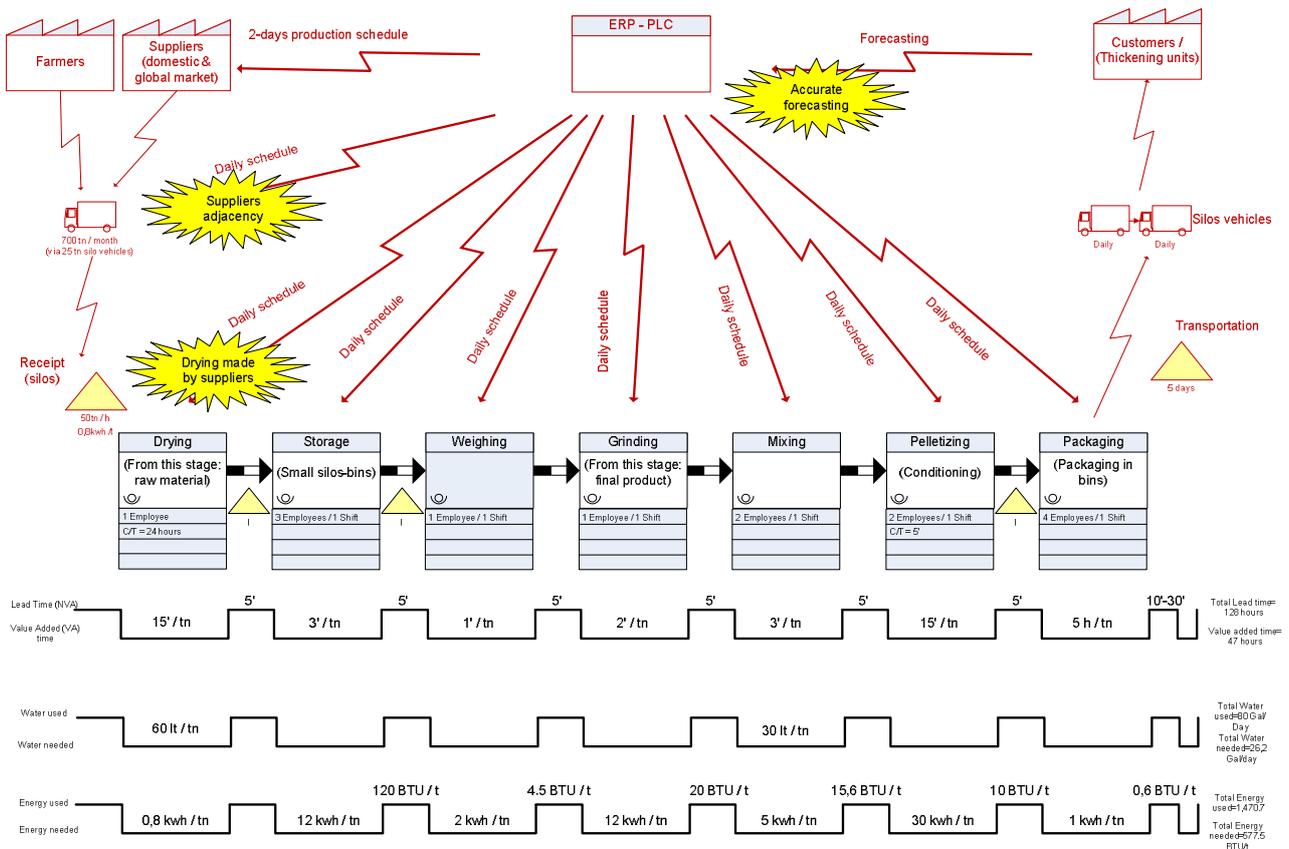


Figure 2. Future State Map

### 3. CONCLUSIONS

This paper provides a perspective of the application of the Lean thinking tools to support the green supply chain and logistics management initiatives. Authors argue that the VSM analysis can be an effective and efficient tool for a number of improvements not only for the identification of the wastes but for the determination of the greening of the agrifood supply chain. The proposed systematic approach was deployed in the corn supply chain for animal feed. Moreover, especially during the economic downhill companies in the agrifood sector and in countries like Greece seek to increase their export efforts. Introducing global supply chain management into the green and lean equation increases the potential conflict between the green and lean initiatives.” So as companies begin to implement lean and green strategies in supply chains, especially large and complex global supply chains, manufacturers need to explore the overlaps and synergies between quality-based lean and environmentally based ‘green’ initiatives, and understand the various trade-offs required to balance possible points of conflict. Finally, there is a need to evaluate and possibly improve this tool, based on practice and the applicability in other sectors as well.

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## COLLABORATION WITH A 4PL PROVIDER FOR THE IMPROVEMENT OF INFORMATION AND INVENTORY FLOWS IN THE TRANSPORTATION PROCESS

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**Abstract:** *In this paper, the complexity of supply chains is highlighted, due to the existence and interactions of multiple supply chain partners. A supply chain collaboration pattern is created, based on literature review, according to which, collaborative relationships must be cultivated among channel partners, in order to optimize the flow of accurate and on time information, thereby enabling the lean flow of inventory, through reduction of the transportation cycle time. To achieve this purpose, the existence of a supply chain integrator, namely a Fourth Party Logistics Provider (4PL), is imminent, in order to handle the complexity of the chain. This need is demonstrated through the analysis of indicative supply chain constructs, displaying the interaction points with intermediaries, and how these are simplified, through collaboration with the 4PL provider to effectively coordinate the end-to-end transportation process. Finally, the supply chain structures are demonstrated through a model.*

**Keywords:** 4PL provider, collaboration, supply chain complexity.

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### 1. INTRODUCTION

The design of the supply chain is a core activity, enabling supply chain managers to propose the optimal logistics network and determine the most suitable distribution channels, taking into consideration the number of plants, suppliers, production capacity, inventories etc. The degree of connectivity appears to play a significant role within the logistics network (Meepetchdee and Shah, 2007).

Organizations are recognized to be complex and adaptive systems (CAS) (Milgate, 2001). Supply chains can also be considered as CAS according to the parallelism provided by Wycisk, McKelvey and Hulsmann (2008), comparing the features of supply networks with CAS properties and behaviors. They suggest that heterogeneous agents, such as suppliers, manufacturers, distributor, commercial representatives, freight forwarders, 3PL providers, etc exist in both constructs, each setting individual goals based on differentiated action patterns. They also believe that interaction is also obvious in the supply chain, in order to properly facilitate the flow of information, inventory and finance. Co-evolution, to them, is evident, as well, since each partner's decision and action influences the entire chain. Finally, they also identify autonomy and self

organization within the supply chain network as individual agents decide and act without direct supervision, without an "outside controller".

The absence of a supply chain integrator preserves the main characteristics of complexity that are related to upstream and downstream uncertainty, technological intricacy and internal and external organizational systems (Milgate, 2001). Since the supply chain complexity directly impacts delivery performance of inventories, the present study will display that the complexity is reduced through close collaboration with "an outside controller", namely the 4PL provider.

In this paper, the significance of collaboration among chain members is presented that allows prompt inventory information flow, thus avoiding the "bullwhip effect" and consequences such as imprecise forecasts, partly exploited capacity, deficient customer service, inventory turns and costs, lack of prompt order fulfillment response (Shore and Venkatachalam, 2003; Caridi, Cigolini and De Marco, 2006). In the section of discussion, indicative supply chain constructs are examined and imprinted, highlighting the interactions among the chain members. Furthermore, the reduction of the interaction effects are indicated, due to the existence of a 4PL provider that operates, based on collaborative schemes, leading to the creation of a networked organization and the relevant supply

chain collaboration pattern, on which the partners' interrelationships must be based. In the final section of conclusion, suggestions are made, in order to further enhance the role of the 4PL provider and improve the information and inventory flows.

## 2. LITERATURE REVIEW

In this section a brief literature review on collaboration is presented, on which the supply chain structures and the proposed supply chain collaboration pattern are based.

### 2.1 The significance of supply chain collaboration

It is of pivotal importance that collaboration is embedded in the processes of information sharing, joint decision making, planning and problem solving, forecasting, distribution, network design, order fulfillment, capacity planning, logistics planning, production scheduling, mutual goals, investments, etc (McLaren, Head and Yuan, 2002; Sahay, 2003; Simatupang and Sridharan, 2005; Stefansson, 2006), in order to exceed the capabilities of a centralized system, and encourage the process of continuous learning (Chiu and Lin, 2004). Co-operation and coordination represent stages prior to collaboration. Co-operation is characterised by the existence of fewer suppliers and long term contracts. Co-ordination is achieved through information linkages, WIP and EDI linkages. What distinguishes these stages from the collaboration phase is joint processes and technology sharing. For the supply chain collaboration to be successfully implemented, inventory systems, information sharing techniques and IT advancements have to be developed, through common financial and relational investments from the channel partners (Maqsood, Walker and Finegan, 2007).

Although many attributes can be reported as vital to the creation of a solid relationship, the key components are trust, transfer of meaningful information and mutual dependence (commitment) (Gibson, Rutner and Keller, 2002). Trust acquisition by observation, trust acquisition by interaction and reputation based trust are enabling mechanisms for the efficient multimodal transportation process (Esfandiari and Chandrasekharan, 2001). Commitment, as an additional feature of collaborative partnership, depends on the contribution of channel partners and the prospects for relationship durability (Wetzels, Ruyter and Van Birgelen, 1998). Additionally, commitment prerequisites healthy communication and transaction- or relation-specific investments, leading

to partner coordination and cooperation (Sheu, Yen and Chae, 2006).

### 2.2. Supply chain structures

Taking into consideration the critical issue of collaboration, the paper recognizes the 4PL provider as the most suitable partner to undertake the reengineering of a supply chain, in that, as the leading firm and simultaneously being the team interface, is able to identify areas that generate revenue and value for both internal and external customers. The main goal is the optimization of inventory flow through the shrinkage of transportation cycle time, which contributes to the effectiveness of the network through the synchronization of best-in-class chain members.

In Figure 1, multiple patterns of supply chains are described that can all differentiate from each other in numerous cases. Moreover, there is not a fixed number of chain participants. For generalization reasons, all categories of third parties involved in the logistics process, such as third party logistics providers, freight forwarding firms, distributors, carriers, etc are considered under the name of "Intermediary". Furthermore, three indicative examples of supply chains are examined.

**In case 1** the manufacturer (M) receives the raw materials or components from  $n$  separate inland suppliers ( $S_1, S_2...S_n$ ) in order for the production or assembly to be executed. The intermediate parties that arrange the transportation can be either external distributors, third parties that cooperate with the supplier or even drivers of the suppliers' fleet. The accurate coordination of the components' arrival at the manufacturers' premises from all suppliers secures the agility of production within the scheduled time interval. In order to achieve this desirable outcome, the logistics manager of the manufacturer must consistently organize and disseminate the relevant information with the suppliers. Further to the production completion, the manufacturer has to arrange the shipment of finished goods to the retailer abroad. In overseas shipments, two agents are involved, i.e. the inland and the corresponding foreign one. Based on the terms of shipment, i.e CIF, FOB, etc, the intermediary (freight forwarder or 3PL provider) contacts a number of carriers, asking for rate offers, transit time, routing and space availability, so that the manufacturer decides which service to use. In case that no freight forwarder or 3PL provider existed, this procedure would have to be carried out by the logistics manager of the manufacturer. The critical point at this stage is the time consuming information exchange and re-evaluation of the carriers' offers.

The intermediaries at both origin and destination are responsible for the customs clearance, packing/unpacking, un/stuffing of container, transport to/ from port, etc. The logistics departments of both the manufacturer and the retailer normally co-ordinate these issues. In case the

retailer agrees to deliver the goods to the final customer, the transportation can be executed either by a 3PL provider or by an independent distributor. The critical point at this phase is the schedule formation with the distributor, so that the final customer receives the order on time.

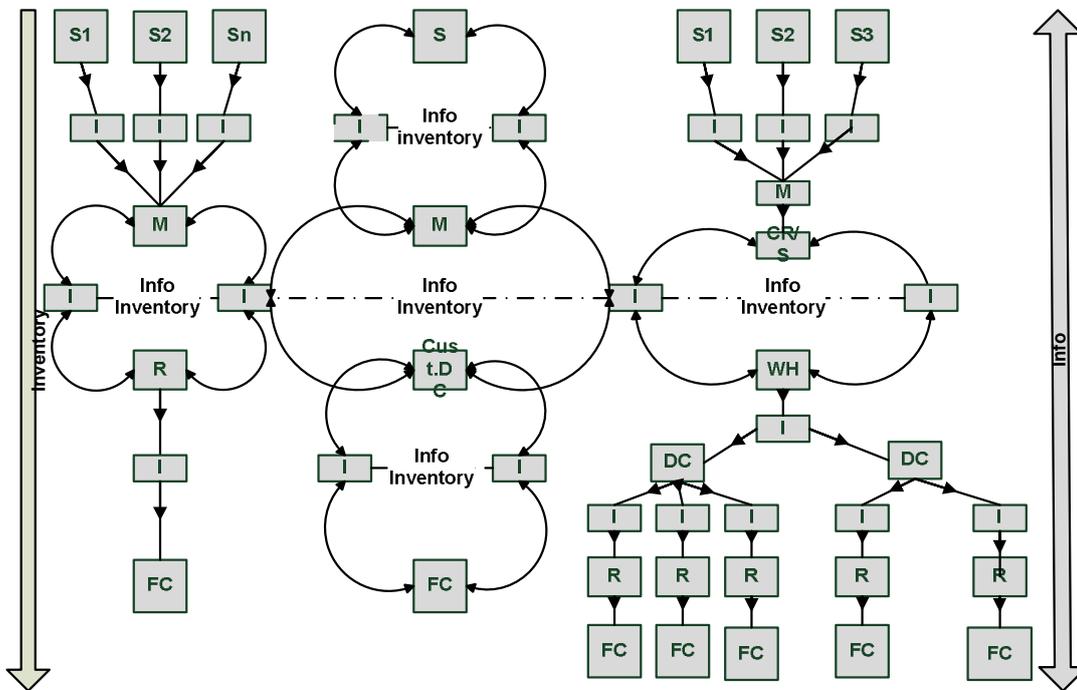


Figure 1. Supply Chain Structures

In **case 2**, another example of supply chain structure is presented, which is interlinked with case 1, in that either the manufacturer or the customer is included in the intermediary's customer base. In this chain, the supplier (S) is established abroad and exports raw materials or components to the manufacturer (M). Depending on the terms of shipment, the same procedure is followed as in case 1, regarding the overseas dispatch. The manufacturer arranges the shipment of finished goods to the Distribution Center (DC) indicated by the consignee. The Distribution Center may be established at a central region/ country that exports to the final customers directly. The involvement of intermediaries is imminent in this phase as well. This market can be assumed to be an on-line market.

In **case 3**,  $n$  inland suppliers (S) provide the manufacturer (M) with the necessary components for production, through distributors. The manufacturer commences the production and holds the inventory either at their premises or at a 3PL provider in order to respond to the shipper's (SH) needs. The shipper plays the role of the commercial representative (CR). Another option is that the shipper undertakes to warehouse the finished goods in order to supply the cooperative wholesaler at

destination accordingly. The critical point here is that the 3PL provider must occupy the appropriate facilities and Information Technology (IT) for the verification of visibility. The intermediary at origin must also undertake the export process in conjunction with the intermediary at destination. The wholesaler (W), on the other hand, has to be aware of the inventory levels at each stage of the chain, so that they can place replenishment orders. Moreover, the wholesaler arranges for the shipment of goods to different distribution centers around the globe. At this point, the close co-operation and collaboration with an International 3PL provider, freight forwarder, or carrier is of great importance, in order for the relevant data to be concentrated on one database. Furthermore, the distribution from the DCs to the retailers can be executed by independent distributors or the cooperatives of an intermediary, so that the goods are available to the final customers.

Based on the above indicative supply chain patterns, more than one buyer, supplier, 3PL provider, freight forwarding or transport company, in general, may be involved in one supply chain, due to global district barriers, and also due to the existence of multiple chain members. This leads to complexity increase, which in turn may result in

delayed and inefficient information retrieval and transmission, forecast errors and inventory accumulation. Manufacturers can avoid operational inefficiencies by taking the entire supply chain into consideration. The responsiveness to customers depends on the punctuality of all supply chain members (Lee and Billington, 1992).

Based on a research conducted by Babbar and Prasad (1998), the challenges to international sourcing can be summarized in JIT sourcing requirements, finding qualified foreign sources, logistics support for longer supply lines, culture and language differences, duty and customs regulations, fluctuation in currency exchange rates, knowledge of foreign business practices, nationalistic attitudes and behavior and understanding the political environment. Additionally, factors that influence success in global sourcing are top management

support, developing communication skills, establishing long-term relationships, developing global sourcing skills, understanding global opportunities, knowledge of foreign business practices, foreign supplier certification and qualifications, planning for global sourcing, obtaining expert assistance, knowledge of exchange rates and use of third-party logistics services. These affairs can be successfully confronted and fulfilled by a 4PL provider, representing the single point of reference in the supply chain network, through centralized control.

The above mentioned types of supply chain can become more agile and lean if all intermediaries are substituted by a 4PL provider, as shown in Figure 2, thus managing to reduce the transportation cycle time, by organizing the logistics processes.

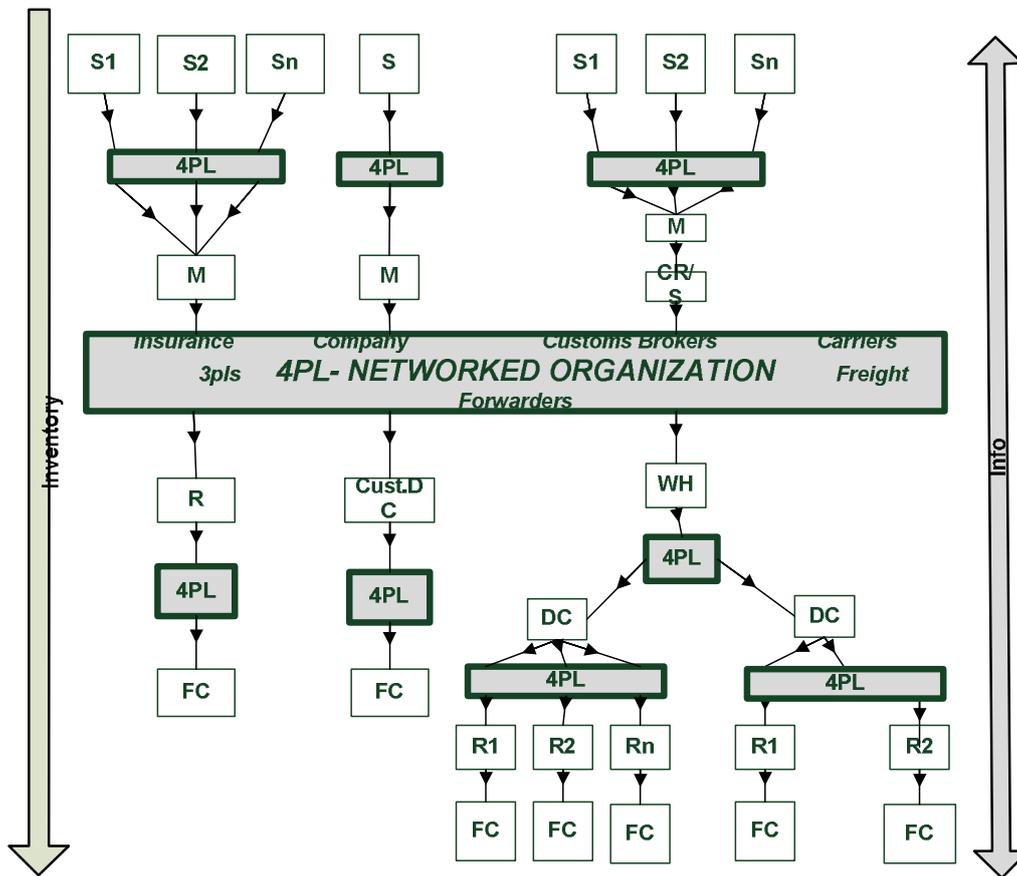


Figure 2. Supply Chain Management through a Networked Organization

Verwijmeren, Van der Vlist and Van Donselaar (1996), introduced the concept of the networked organization that is also adopted in this paper, as it accurately describes the role of the 4PL provider. According to their study, “a networked organization is an organization (company or business unit) with its own strategic control unit that co-operates with other organizations, on the tactical and operational

level, within its strategic constraints, in order to gain mutual benefits”. Furthermore, the organizations that comprise a network depend on long-term value adding relationships among synchronized enterprises, sharing mutual goals, responsibilities, accountability and trust.

These features represent the main characteristics of a 4PL provider and the overall idea of supply

chain networking. The attributes of the networked organization verify the outcomes of the extensive literature review, that the success of the 4PL concept is strongly related to the notion of supply chain collaboration. Integrating the components that

comprise collaboration, this paper suggests a Supply Chain Collaboration Pattern that can be used by supply chain consultants or internal auditors, in order to verify the existence of true collaboration.

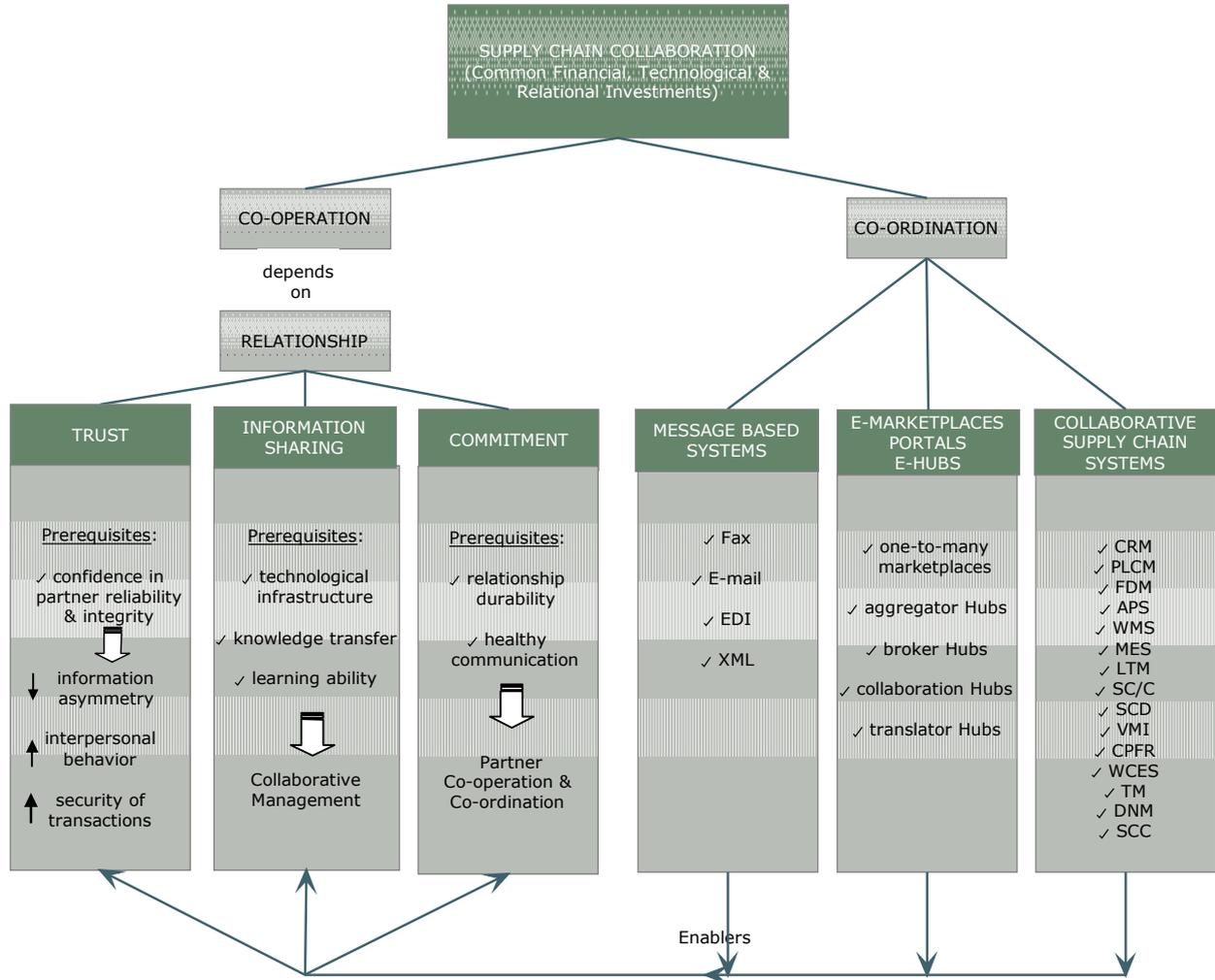


Figure 3. Supply Chain Collaboration Pattern

### 3. CONCLUSION

The need for synchronization imposes the necessity that the logistics departments at each echelon make intense efforts to coordinate and direct the structure properly. The existence of a supply chain leader is imperative, in order to identify the value generators and guide the supply chain towards this direction. A fourth party logistics provider can undertake this role, in that it can create a network consisting of all types of best-of-breed asset based providers, under an upgraded technological umbrella, thereby enabling flexibility and efficiency. Consequently, it can assist the future entrepreneur prior to the company establishment. Through a proper IT application, the 4PL can examine

numerous logistical scenarios on account of its customers, in order to decide on the appropriate construct of the supply chain.

Furthermore, through commonly shared Information and Communication Technology (ICT) systems, joint decision making and planning, product design, demand forecasting, production scheduling, distribution, order fulfillment, capacity planning are encouraged, based on mutual goals among the network partners. The collaborative environment, in which the 4PL operates, enhances the sharing of knowledge and experiences among partners, promoting continuous learning and improvement. The 4PL gathers information from all chain patterns, which it further assesses and disseminates the exact amount of information to the

relevant parties, avoiding to provide them all with unuseful details.

Furthermore, the 4PL can gather critical information about the economic, political and social conditions of each country through its global partners and disseminate it to the interested parties. Such process is of major importance taking into consideration that specific facts, such as a war can cause delays and lead to distorted flow of inventory.

To conclude, a 4PL represents a networked organization, sharing goals responsibility, accountability and trust. Networked inventory management can be facilitated by a sequence of co-operating and collaborating partners, aiming at quality optimization at all stages.

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# DECONRCM: A WEB-BASED TOOL FOR THE OPTIMAL MANAGEMENT OF WASTE FROM CONSTRUCTION ACTIVITIES

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**Abstract:** Construction and demolition waste (CDW) constitute the largest by quantity fraction of solid wastes, especially in urban areas. It is also widely accepted that the particular waste stream contain hazardous materials, such as insulating materials, plastic frames of doors and windows etc. Uncontrolled disposal of waste from construction activities result to long-term pollution costs, resource overuse and wasted energy. Towards environmental-friendly management of CDW, a web-based Decision Support System (DSS) has been developed, namely DeconRCM, which aims towards the identification of the optimal degree of buildings' deconstruction or demolition in order to minimise constructions' end-of-life costs (including logistics costs for the transportation of end-of-life building materials to certified recycling/disposal companies) and maximise recovery of salvaged building materials. This paper addresses both technical and functional structure of the developed web application, while also presents the software's results for a number of buildings in the Greater Thessaloniki Area, Greece.

**Keywords:** Construction and demolition waste, demolition, deconstruction, DeconRCM.

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## 1. INTRODUCTION

As concerns the environment, the construction industry has proven as one of the most pressing sectors, both for the consumption of natural resources, as well as for the release of pollutants to the natural environment. Construction and Demolition Waste (CDW) stream, accounts to an estimated 30 – 35% of the overall municipal solid waste (MSW) stream internationally [11]. Construction and demolition waste (CDW) include a wide range of materials depending on the source of the waste [7], namely:

- excavation materials (e.g. earth, sand, gravel, rocks and clay),
- road building and maintenance materials (e.g. asphalt, sand, gravel and metals),

- demolition materials (e.g. debris including earth, gravel, sand, blocks of concrete, bricks, gypsum, porcelain and lime-cast),
- other worksite waste materials (e.g. wood, plastic, paper, glass, metal and pigments).

Despite the fact that this particular waste stream presents the third largest in quantities, only following waste from the mining and farming industry [5], up to recently, common practice was to discard CDW materials and debris in landfills, most often the same ones built for the disposal of MSW [8]. Moreover, it is often reported that large quantities of CDW end up in uncontrolled open dumps, which presents a significant burden for the environment.

Environmental impacts of such practices include soil and water contamination, air pollution as a result of resulting fires, reduced land and property values, destruction of open spaces, aesthetic degradation and

landscape blight [6]. In addition, CDW may include asbestos waste, which poses a significant health risk, especially in building sites which are later converted into residential areas or playgrounds [9].

In order to assist construction companies, public bodies, engineers and individuals towards environmental-friendly sound management of CDW, a web-based Decision Support System (DSS) has been developed, namely DeconRCM. A beta version of DeconRCM can be visited at: <http://pandora.meng.auth.gr/deconrcm>. Currently, the application is built for the case of the Region of Central Macedonia, Greece, but can be easily expanded to other areas with the necessary adjustments [4]. In this paper, functional specifications of DeconRCM are provided, together with a brief description of its technical aspects.

## 2. DEVELOPMENT OF “DeconRCM” DECISION SUPPORT SYSTEM

DeconRCM addresses the needs of specific target groups such as, contractors, engineers and public stakeholders. In brief, DeconRCM provides an accurate estimation of the generated quantities of 21 different waste streams produced by two main processes (renovation and demolition - R&D) of four building types (residential, office, commercial and industrial), based on the typical construction practice in Greece [2]. Furthermore, DeconRCM provides the user with the optimal management of each generated R&D waste stream regarding both economic and environmental criteria.

DeconRCM's structure and data flow are depicted in Figure 1. The basic scope of DeconRCM is to provide the end user with an easy to use tool for:

- the total volume of the CDW produced either from a demolition or renovation constructional process,
- the optimal CDW management,
- the optimal route from the construction sites to the deposition sites, and
- the overall CDW management cost.

DeconRCM is built with the use of a web mapping via Google Maps API (free web mapping service application and technology provided by Google that powers many map-based services, including the Google Maps website via Google Maps API). A database with all the adequate information regarding the disposal sites of the Region of Central Macedonia, Greece is embodied in the application. The database, which is based on MySQL, can be accessed and edited only by the

administrator of the portal. Feedback forms, based on php 5.0 scripting language, are developed for gathering data as regards the source site (demolished or renovated building). Additionally, an algorithmical model, built with the use of excel spreadsheets, is constructed and embodied in the DSS tool for the estimation of the generated quantities of R&D wastes from a building. The output of quantity estimation model is stored in databases, also developed with MySQL. Finally, optimisation of the integrated CDW management of end-of-life buildings is solved with the use of a mixed-integer linear programming model (MILP). The full description of the tool's technical and functional specifications are provided in [3].

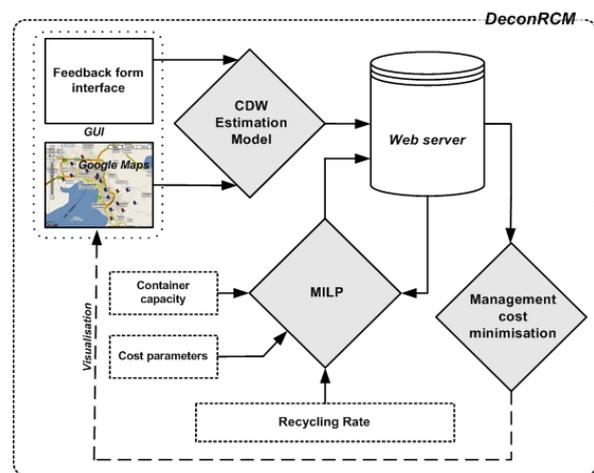


Figure 1. Structural components of DeconRCM

On top of the above, DeconRCM's user is required to insert a series of data that is essential in order to define the abovementioned parameters. In detail, by accessing DeconRCM the user has to determine the exact position of the case under review in the map. At the same time, the user must, both choose the constructional activity (demolition/renovation) that takes place and to define the kind of each building category (detached house/block of flats, office building and industrial building) (Figure 2).

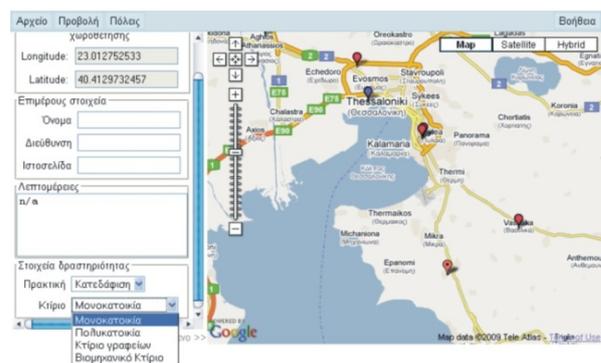


Figure 2. DeconRCM's interface of building and construction determination

Moreover, the user has to set in the feedback forms the technical characteristics and/or details of each building type. In case of a residence building demolition (whether it is a detached house or a block of flats) the user should be in position to set the following characteristics concerning the building (Figure 3):

- construction year,
- building dimensions and number of floors,
- ground floor usage (residence, parking or pilotis),
- roof type,
- existence of basement and elevator,
- total balcony surface,
- heating type system and number of radiators per floor,
- number of apartments and WCs per floor,
- total number of windows per floor,
- type and number of frames (aluminum, timber, plastic),
- number of internal walls.

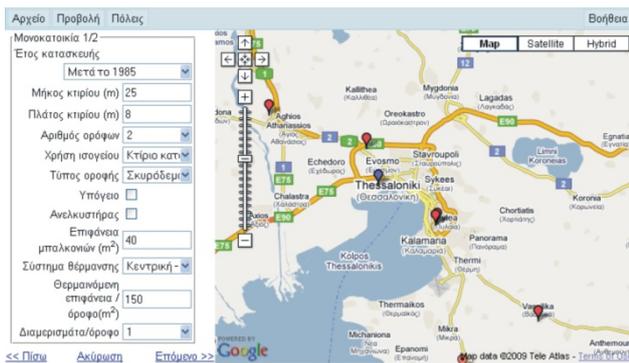


Figure 3. DeconRCM's interface of building and construction characteristics

Figure 4 depicts the information and result management interface which include the "Information" and "Calculation" tabs. By clicking the field "CDW quantities" the total amount of produced waste is presented.

Data input, as it was fully described above in the DeconRCM application forms, allows the user to depict the total CDW volume produced by the selected constructional activity. More specifically, finding and choosing the building that was defined in the map leads to the window with the tabs entitled "Information" and "Calculation" (Figure 5).

Optimisation of the integrated CDW management is solved with the use of a mixed-integer linear programming (MIPL) model [1]. Cost parameters that are included are:

- i. the fixed deconstruction process cost,

- ii. the fixed cost of demolishing the entire building,
- iii. the fixed demolition process cost,
- iv. the variable cost of deconstructing the building (€/t),
- v. the variable cost of separating CDW, plus loading cost in container for each material,
- vi. the fixed cost of using/renting a container and
- vii. the variable cost of a container to a disposal site (€/container).

Revenues from secondary materials' sales are also considered [1].

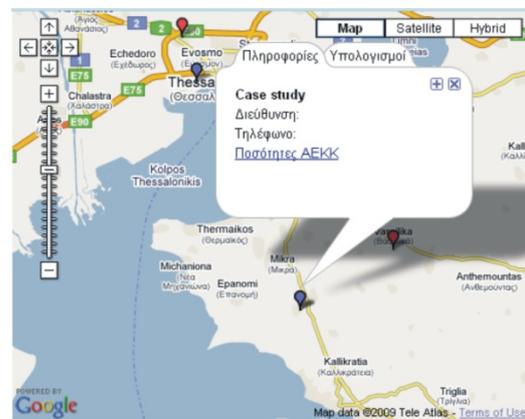


Figure 4. DeconRCM's information and result management interface

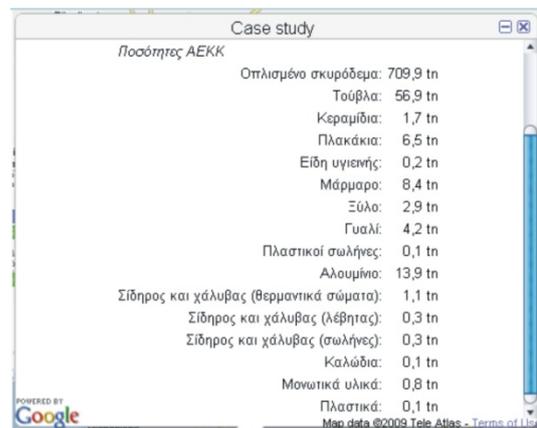


Figure 5. DeconRCM's CDW quantities interface

### 3. APPLICATION AND MANAGERIAL INSIGHTS

The applicability of DeconRCM has been demonstrated and its results have been validated elsewhere [4]. In the framework of the present work additional applications of the DSS are presented and statistically analyzed in order to obtain useful managerial insights as regards CDW management. More specifically, DeconRCM was used in order to

assess CDW quantities and management cost for twenty seven residential buildings in the Greater Thessaloniki Area. More information about the specific case studies is reported in the work of [10].

**Table 1. CDW quantities and managerial cost for thirty residential buildings in the Greater Thessaloniki Area**

Building id	Concrete	Brick	Tile	Porcelain	Marble	Timber	Glass	Plastic	Aluminium	Metal	Management cost
(#)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(t)	(€)
1	814.3	80.8	1.3	0.9	37.8	0.1	1.3	0.1	4.3	0	19,034
2	814.3	71.1	1.3	0.9	37.8	0.1	1.3	0.1	4.3	0	18,825
3	1760	92.5	1.8	1.1	102.8	0.1	3.9	0.3	12.8	4.4	27,136
4	395.7	33.3	-	0.2	-	2.1	1.5	0.1	5	0.7	2,906
5	255.2	16.6	0.8	-	-	0.1	0.5	0	1.6	0.5	4,294
6	2196.4	118.5	1.9	1	90.7	0.1	4.6	0.2	15.4	2.5	36,714
7	1040.4	77.9	1	0.8	37.6	2.8	2	0.2	6.9	1.8	16,970
8	4254.4	299.6	-	3.4	254	0.1	6.5	0.6	21.7	11.7	80,744
9	3662.1	200.3	3.7	1.4	181.4	0.1	2.6	0.3	8.8	4.2	91,569
10	1859	78.9	2.3	0.8	90.7	0.1	3.7	0.2	12.3	1.9	33,883
11	4704.4	328.5	-	3.4	302.4	0.1	2.4	0.6	9.7	11.4	114,545
12	464.4	39.2	0.8	0.2	14.8	0.1	1.2	0.1	3.8	0.7	7,053
13	1571.6	71.9	1.3	1.4	64.7	0.1	3.5	0.3	11.8	4	22,598
14	218.1	10.2	-	-	-	0.1	0.5	0	1.6	0.6	3,028
15	2489.7	124.8	2.3	1.9	113.4	0.1	6	0.4	20	6.1	34,826
16	1971.7	103.9	1.7	1	109.2	-	2.4	0.1	6.3	1.6	48,416
17	1702.9	103.8	1	1.1	60.5	4.9	4.9	0.2	11.2	2.1	31,055
18	1519.5	79.1	1.7	0.8	67.2	4.4	2.4	0.2	7.9	1.9	31,456
19	645.7	73.5	1.7	0.6	33.6	8.2	1.4	0.2	4.9	2	10,109
20	3722.2	123.5	3.2	1.4	157.5	10	5.1	0.3	17.1	4.1	78,377
21	1818.8	99.6	1.9	1.1	74.3	11.1	3.7	0.2	11.6	2.5	33,229
22	2653.1	98.6	1.9	1.7	108.9	12	6.1	0.3	20.6	5	39,480
23	530	61.9	0.8	0.3	24.2	4.4	0.9	0.1	2.4	1	11,627
24	6148.7	323.5	-	2.3	349.4	27.7	3.9	0.4	10.3	7.7	162,239
25	3473	149.6	2.6	1.1	151.2	5.7	3	0.2	10	2.5	84,879
26	2500.4	154.3	3.5	1.1	134.4	17.7	2.5	0.2	8.3	2.7	60,232
27	2308.8	90	3.1	0.8	93.1	9.2	2.3	0.2	-	2.3	65,857
avg	2271.6	119.7	2.0	1.3	132.7	4.5	3.2	0.2	10.6	3.5	101,145

It should be noted that all figures in Table 1 are calculated for a recycling rate of 50%. The average percentage of the different CDW streams are illustrated in Figure 6.

Figure 7 illustrates the relevance between CDW quantities and its management cost for the cases under consideration.

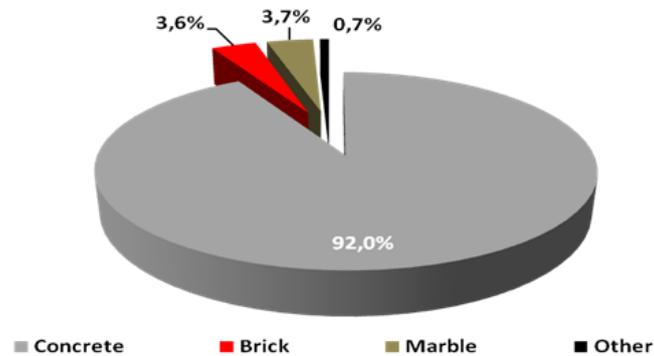


Figure 6. CDW streams' percentages

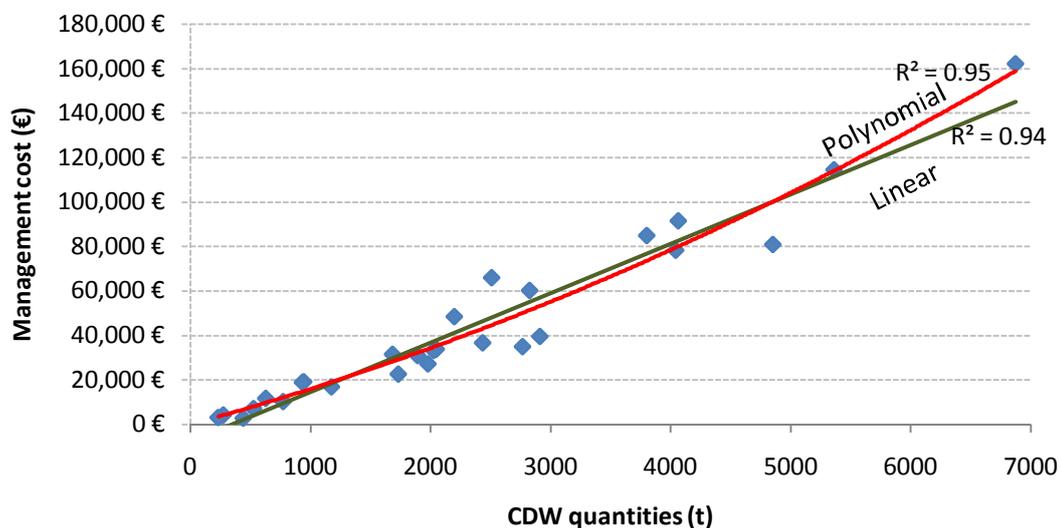


Figure 7. CDW quantities and management cost

#### 4. CONCLUSIONS

CDW is a “priority” waste stream for the European Union, mainly due to its rapid growth over the last years. In this paper the technical and functional characteristics for the development of a web-based DSS application, namely DeconRCM are presented. Moreover, the software’s results for a number of buildings in the Greater Thessaloniki Area, Greece are presented.

DeconRCM’s major advantage lies in its web-based technology. There are several reasons in favour of a web-based DSS, e.g. raise of awareness, enhancement of detailed knowledge and encouragement of specific target groups’ commitment towards sustainable CDW management. In addition, DeconRCM’s “look-and-feel” user interface enables users -who do not always have the adequate scientific background- to

retrieve information and navigate through data interactively.

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# END-OF-LIFE VEHICLE RECYCLING IN THE REPUBLIC OF SERBIA: INTERVAL LINEAR PROGRAMMING MODEL FOR LONG-TERM PLANNING UNDER UNCERTAINTY

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**Abstract:** Nowadays, end-of-life vehicles (ELVs) are considered as a burning environmental issue, since this kind of waste contains many precious metals. Recycling and reuse of ELV parts and components, and metal recovery are important to governments, manufacturers, suppliers, dismantlers and vehicle recycling factories worldwide. Current, not so bright, situation in the Republic of Serbia regarding the recycling of ELVs and a noticeable tendency towards creation of economically sustainable recycling system represent major motives for projection and modeling of vehicle recycling system that would be the most cost-effective and eco-efficient in the long run. In this paper, interval linear programming (ILP) approach is used to formulate model for optimal long-term planning in the Serbian vehicle recycling factories under uncertainty. Presented ILP model is valuable for supporting the construction and/or modernization process of vehicle recycling system in the Republic of Serbia.

**Keywords:** End-of-life vehicle, Interval linear programming, Republic of Serbia, Serbian ELV Ordinance, Uncertainty.

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## 1. INTRODUCTION

The management of special wastes flows is currently one of the most important ecological topics worldwide. From the angle of quantity, end-of-life vehicles (ELVs) represent one of top priority wastes.

ELV recycling problem has in the last several years become rather important in the Republic of Serbia as well. By passing the National strategy of waste management with the attached EU advancement program, Waste management law, Waste management strategy for period 2010-2019 and the Ordinance on the management of ELVs in the Republic of Serbia (Serbian ELV Ordinance) (MERS, 2010), the Government managed to include Serbia in the group of countries that took long term solving of vehicle recycling problem responsibly and constructively.

In the Republic of Serbia, there is no vehicle recycling system. This process is carried out only in a few simple plants for recycling of metal waste that are in no way sufficiently equipped to successfully respond to this exceptionally complex task. On the other hand, vehicle recycling issue is being given more attention, especially since 2008 when the new Waste management law was passed. However,

although article 55 of this Law is dedicated to the management of ELVs, from the vehicle recycling aspect this regulation cannot be considered contemporary. That is why the Waste management strategy for period 2010-2019, passed in May 2010, pays special attention to the vehicle recycling problem. This strategy clearly emphasizes the need to set up economically sustainable vehicle recycling system as soon as possible. The Serbian ELV Ordinance came into effect in December 2010 and Appendix 3, in the tradition of the Directive on end-of-life vehicles 2000/53/EC (EU ELV Directive), regulates ecological requirements for collection, reuse and recycling of ELVs. More detailed, from January 1, 2015, recycling rate and recovery rate must not be smaller than 80% and 85% respectively, while energy recovery rate cannot be more than 5%. Additionally, on January 1, 2019, of stringent quotas are planned to be introduced: minimal rates of recycling and recovery of 85% and 95% respectively, and maximal energy recovery rate of 10%.

The main objective of this paper is to develop an interval linear programming (ILP) model for long-term planning of vehicle recycling in the Republic of Serbia. This model could have significant practical value, as it may serve as the basis for the

development of modern recycling system in the Republic of Serbia.

The remaining part of the paper is organised as follows: Section 2 presents review of state-of-the-art papers published in the past five years. Section 3 presents the used methodology, and developed ILP model. Section 4 presents preliminary results analysis and short discussion. Section 5 presents the paper's main conclusions.

## 2. LITERATURE REVIEW

In this section, an overview of the recent literature related to the environmental engineering issues in the area of ELV recycling is performed in order to identify the key direction(s) for the further development of this very dynamic research area.

Kumar and Sutherland (2009) created a simulation model for material flows and economic exchanges to examine the effects of changes in vehicle material composition on the US recycling infrastructure. They found that with change in vehicle design the profit of vehicle recycling factories will increase over time, due to the additional revenue from the aluminium in aluminium intensive vehicle hulks.

Mathieux and Brissaud (2010) proposed method to build an end-of-life product specific material flow analysis and applied it to aluminium coming from end-of-life commercial vehicles in EU. However, they pointed out that the implementation of the method requires a lot of field effort.

Vermeulen et al. (2012) proposed a set of seven sustainability indicators suitable for assessing and comparing industrial waste treatment processes. The proposed overall sustainability assessment method is applied to ASR case study. It is outlined that recycling combined with energy recovery was the most sustainable processing strategy as it enabled to reach the EU ELV Directive quotas set by 2015. Simić and Dimitrijević (2012b) presented a tactical production planning problem for vehicle recycling factories in the EU legislative and global business environments. They analyzed influence of the EU ELV Directive on the vehicle recycling facilities business and concluded that future eco-efficiency quotas will not endanger their profitability. In addition, they recommended that the control of the recycling system efficiency should be done at the system level because it will in no way jeopardise the EU ELV Directive objectives. Simić and Dimitrijević (2012a) expanded linear programming modelling framework proposed by Simić and Dimitrijević (2012b) in order to incorporate vehicle hulk selection problem and to answer to the

following questions: Can contemporary equipped vehicle recycling facility conduct profitable business? Are EU ELV Directive's eco-efficiency quotas actually attainable? How will the commenced change in vehicle design influence vehicle recycling facilities? To do so, they provided a production planning model of a contemporary equipped vehicle recycling facility and tested it extensively using real data. They came to the conclusion that vehicle recycling facility transformation, from traditional to contemporary equipped, is not only necessary but completely justified and that the final success of the EU ELV Directive is realistic.

Simić and Dimitrijević (2013a) proposed a short-term ASR recycling planning model for Japanese vehicle recycling industry, which can be used to improve its profitability and recycling efficiency. The change in vehicle design, observed from the aspect of substituting ferrous metals with aluminium, will not jeopardize Japanese vehicle recycling system. Influence of the Japanese law on recycling of ELVs is found to be crucial for the decision making on ASR recycling, as the 20% increase in valid ASR recycling quota will cause approximately 50% decrease in the quantity of disposed ASR. Simić and Dimitrijević (2013b) developed a risk explicit interval linear programming model for optimal long-term planning in the EU vehicle recycling factories to analyze the linkage and trade-offs between decision risk and system performances. They found that introduction of the stringent eco-efficiency quotas will radically reduce the quantity of land-filled wastes in EU; waste quantities routed to the landfills will be reduced from 3.5 to 11.0 times, the waste shipped to the ATT plants will be larger in quantity than the waste shipped to the landfills, while the waste combustion in MSWIs will increase to up to 4.4 times.

From the review of previous literature, it is evident that there is a lack of research of uncertainties that exist in vehicle recycling planning and none of the previous studies analysed vehicle recycling problem in the Republic of Serbia. Moreover, not so bright situation in the Republic of Serbia regarding the recycling of ELVs and a noticeable tendency towards creation of economically sustainable recycling system represent additional motives for projection and modelling of vehicle recycling system that would be the most cost-effective and eco-efficient in the long run. On the other hand, in a vehicle recycling system, it is difficult to express or obtain the overall modelling data in deterministic form. However, they all can be obtained as interval values and the approach to

tackling such a problem is called interval linear programming. It can deal with the uncertain modelling parameters expressed as intervals without any distributional information. Therefore, ILP approach is used in this paper to describe and treat imprecise and uncertain parameters.

### 3. METHODOLOGY

#### 3.1 Overview of the projected Serbian vehicle recycling system

Fig. 1 presents flow diagram of the projected vehicle recycling system in the Republic of Serbia. It was created on the basis of the following documents: 1. Serbian ELV Ordinance; 2. Waste management strategy for period 2010-2019; 3. Waste management law; 4. National strategy of waste management with the attached EU advancement program.

It is evident in Fig. 1 that there are four actor groups involved in vehicle recycling procedure in the Republic of Serbia. The first group includes vehicle users that are at the same time also network sources. This group consists of new vehicle buyers, second-hand vehicle buyers and/or last owners. Every vehicle user is required to deliver ELV to the person that does collection and/or its primary treatment, i.e. dismantling (MERS, 2010).

The second group is represented by collection agents and dismantling companies. Collection agents entity consists of scrap yards, vehicle dealers and repair shops. Serbian ELV Ordinance enacted that they must have proper license to conduct this business and storage space.

Vehicle recycling factory represents dominant participant of the projected system. Besides, currently there is no vehicle recycling factory in the Republic of Serbia, but the integrated process of dismantling and primary recycling is done only in several plants for metal waste treatment. More detailed, Serbian Government allowed recycling of end-of-life vehicles to only nine companies. They are by no means sufficiently equipped to successfully fulfil the very complex task of vehicle recycling. That is why it is necessary to build a vehicle recycling factory as soon as possible, as it would have significance not only for the Republic of Serbia, but for the whole region as well.

Lastly, the fourth actor's group consists of seven final destinations. In integrated recycling system, vehicle recycling factory can allocate sorted waste flows to several waste entities, i.e. landfill, MSWI or ATT plant. It should be mentioned that in the region there isn't a single plant for advanced thermal treatment and that is why this entity is presented

with dashed line in Fig. 1. In addition, municipal solid waste incinerator does not exist in the region. On the other hand, sorted metals can be allocated to steel mill, copper production plant and aluminium production plant. Collected insulated cooper wires are sold to secondary material buyers for further recycling.

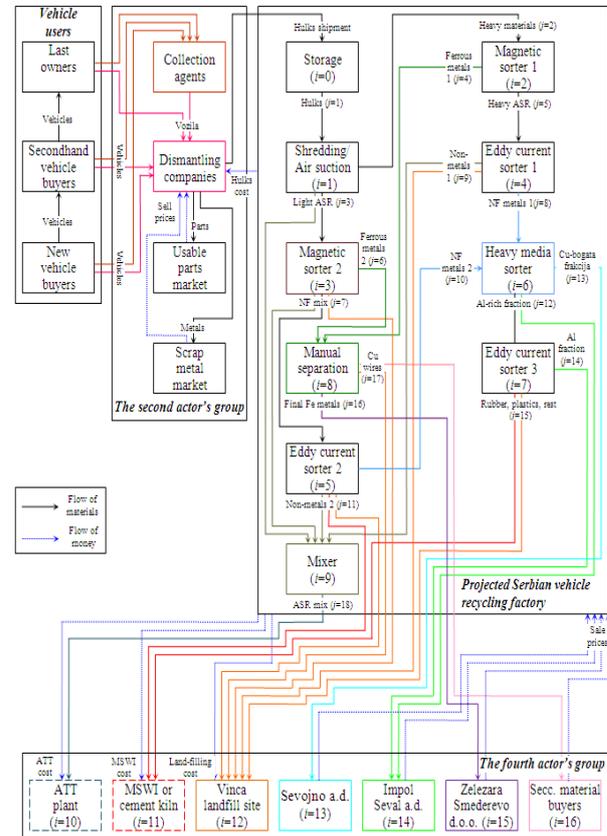


Figure 1. Flow sheet of the projected Serbian vehicle recycling system

#### 3.2 ILP model for long-term planning of vehicle recycling in the Republic of Serbia under uncertainty

Many methods have been developed to deal with uncertainties. One of them is the ILP method (Tong, 1994).

The proposed model tackles a long-term end-of-life vehicles recycling planning problem in the Republic of Serbia. Its objective is to maximize profit of the projected contemporary equipped vehicle recycling factory over the planning horizon. The formulated model provides optimal interval solutions for procurement, storage, hulk shredding, processing liberated material fractions, recycling, advanced thermal treatment (if plant of this type is available), incineration in MSWI (if incinerator is available or incineration is arranged with the local cement kiln) and land-filling. It is formulated as follows:

$$\begin{aligned} \text{Max } f^\pm = & \sum_{t=1}^T \sum_{i'=I-|M|}^{I-1} \sum_{i \in \Omega_{i'}} R_{ii't}^\pm X_{ii't} - \sum_{t=1}^T CP_t^\pm P_t \\ & - \sum_{t=1}^T \sum_{i'=1}^{I-I'-2} \sum_{i \in \Omega_{i'}} CS_{i't}^\pm X_{ii't} - \sum_{t=1}^T Z_t^\pm CP_t^\pm S_t \\ & - \sum_{t=1}^T (CA_t^\pm + CB_t^\pm) Y_t - \sum_{t=1}^T \sum_{i'=I-I'+1}^{I-1} \sum_{i \in \Omega_{i'}} CT_{i't}^\pm X_{ii't} \\ & - \sum_{t=1}^T CM_t^\pm \sum_{i' \in \Omega_{I-I'+1}} X_{i'I-I'+1t} \\ & - \sum_{t=1}^T CL_t^\pm \sum_{i \in \Omega_{I-I'+2}} X_{iI-I'+2t} \end{aligned} \quad (1)$$

subject to:

$$S_t = \begin{cases} P_t + S_0 - X_{01t}, & \text{if } t=1 \\ P_t + S_{t-1} - X_{01t}, & \text{if } t=2, \dots, T \end{cases} \quad (2)$$

$$S_t \geq S_{min}^\pm, \quad t = 1, \dots, T \quad (3)$$

$$\sum_{i' \in \Omega_i} V_i^\pm X_{i'it} \leq \Lambda, \quad i = 1, \dots, I - I' - 2; \quad t = 1, \dots, T \quad (4)$$

$$\sum_{i'' \in \Psi_j} X_{ii''t} = E_{ij}^\pm \sum_{i' \in \Omega_i} X_{i'it}, \quad i = 1, \dots, I - I' - 2; \quad j \in A_i; \quad t = 1, \dots, T \quad (5)$$

$$\sum_{j \in A_i} \sum_{i'' \in \Psi_j} X_{ii''t} = \sum_{i' \in \Omega_i} X_{i'it}, \quad i = 1, \dots, I - I' - 2; \quad t = 1, \dots, T \quad (6)$$

$$Y_t = \sum_{i \in \Omega_{i'}} X_{ii't}, \quad i' = I - I' - 1; \quad t = 1, \dots, T \quad (7)$$

$$\sum_{i' \in M} \sum_{i \in \Omega_{i'}} X_{ii't} + ER_{I-I'}^\pm Y_t \geq Q_R X_{01t}, \quad t = 1, \dots, T \quad (8)$$

$$\begin{aligned} & \sum_{i' \in M} \sum_{i \in \Omega_{i'}} X_{ii't} + (ER_{I-I'}^\pm + EE_{I-I'}^\pm) Y_t \\ & + EE_{I-I'+1}^\pm \sum_{i \in \Omega_{I-I'+1}} X_{iI-I'+1t} \geq Q_R X_{01t}, \quad t = 1, \dots, T \end{aligned} \quad (9)$$

$$EE_{I-I'}^\pm Y_t + EE_{I-I'+1}^\pm \sum_{i \in \Omega_{I-I'+1}} X_{iI-I'+1t} \leq Q_E X_{01t}, \quad t = 1, \dots, T \quad (10)$$

$$P_t \geq 0, S_t \geq 0, Y_t \geq 0, \quad t = 1, \dots, T \quad (11)$$

$$X_{ii't} \geq 0, \quad i = 0, \dots, I - I' - 2; \quad i' \in \Phi_i; \quad t = 1, \dots, T \quad (12)$$

In previous modelling formulation *indices and sets* are:  $i$  is index of entity;  $i \in \{0, \dots, I-1\}$ ;  $j$  is index of material flow;  $j \in \{1, \dots, J\}$ ;  $t$  is index of time period;  $t \in \{1, \dots, T\}$ ;  $A_i$  is set of material flows isolated with sorting entity  $i$ ;  $i \in \{1, \dots, I-I'-2\}$ ;  $\Psi_j$  is set of entities on which material flow  $j$  is forwarded;  $j \in \{2, \dots, J\}$ ;  $\Omega_i$  is set of entities that route materials to entity  $i$ ;  $i \in \{1, \dots, I-1\}$ ;  $\Phi_i$  is set of entities on which materials are routed from entity  $i$ ;  $i \in \{0, \dots, I-I'-1\}$ ; and  $M$  is set of various metal producers in the

Republic of Serbia. *Parameters* of developed model are:  $I$  is number of entities;  $J$  is number of material flows;  $T$  is number of analysed time periods;  $I'$  is number of destinations;  $S_0$  is initial inventory weight of vehicle hulks;  $S_{min}^\pm$  is interval value of safety inventory level;  $V_i^\pm$  is interval value of processing time per unit weight on entity  $i$ ;  $\Lambda$  is duration of planning period in time units;  $ER_i^\pm$  is interval value of recycling efficiency of destination  $i$  in percentages;  $EE_i^\pm$  is interval value of energy efficiency of destination  $i$  in percentages;  $E_{ij}^\pm$  is interval value of efficiency of sorting entity  $i$  in the case of material flow  $j$  in percentages;  $Q_R$  is Serbian ELV Ordinance recycling quota;  $Q_R'$  is Serbian ELV Ordinance recovery quota;  $Q_E$  is Serbian ELV Ordinance energy quota;  $R_{ii't}^\pm$  is interval value of revenue from each unit weight of metal fraction sorted on entity  $i$  and sold to destination  $i'$  in period  $t$ ;  $CA_t^\pm$  is interval value of advanced thermal treatment cost in period  $t$  per weight unit;  $CM_t^\pm$  is interval value of incineration cost in MSWI or cement kiln in period  $t$  per weight unit;  $CB_t^\pm$  is interval value of transportation cost per weight unit of ASR mix fraction in period  $t$ ;  $CL_t^\pm$  is interval value of land-filling cost per weight unit in period  $t$ ;  $CP_t^\pm$  is interval value of vehicle hulks procurement cost per weight unit in period  $t$ ;  $Z_t^\pm$  is percentage of capital cost for inventory in period  $t$ ;  $CS_{i't}^\pm$  is sorting cost per weight unit in the case of entity  $i$  and period  $t$ ; and  $CT_{ii't}^\pm$  is transportation cost from entity  $i$  to destination  $i'$  per weight unit in period  $t$ . Finally, *variables* of developed model are:  $S_t$  is weight of vehicle hulks in storage at the end of period  $t$ ;  $P_t$  is weight of incoming vehicle hulks procurement in period  $t$ ;  $X_{ii't}$  is weight of material flow routed from entity  $i$  to  $i'$  in period  $t$ ; and  $Y_t$  is weight of ASR mix fraction in period  $t$ .

The objective function (1) seeks to maximise the vehicle recycling factory's profit over the planning horizon. In the objective function, the first term represents income from sale of the isolated metals. The second term of the objective function represents procurement costs of vehicle hulks from dismantling companies, the third term calculates material fragmentation and sorting costs, and the fourth term relates to the storage cost for hulks that have not

been assigned for recycling. The fifth term of the objective function calculates cost for advanced thermal treatment of isolated ASR. The sixth term of the objective function relates to transportation costs of sorted metals to the final destinations and isolated waste materials to the waste entities. The sixth term of the objective function defines costs of incineration in MSWI or in cement kiln. The last term of the objective function calculates the costs of land-filling.

Constraints (2) enforce the inventory balances. Constraints (3) ensure the safety stock level of vehicle hulks in order to protect the shredder from starvation. Constraints (4) represent the processing capacity of shredder and sorting entities, while constraints (5)–(6) maintain their material flow balance. Constraints (7) describe operations of mixing light ASR fraction, non-ferrous mix fraction, the first and the second non-metals fractions into the ASR mix fraction. The presence of constraints (7) in the model for long-term planning of vehicle recycling in the Republic of Serbia under uncertainty makes sense only when ATT plant is available. Constraints (8)–(10) represent specific eco-efficiency requirements imposed by the Serbian ELV Ordinance. Finally, constraints (11)–(12) define the value domains of decision variables used in the proposed model.

#### 4. RESULT ANALYSIS AND DISCUSSION

In this section formulated model is applied to a numerical case study which analyzes period 2013–2014 (characterized with the absence of law regulation on the vehicle recycling system in the Republic of Serbia), three scrap metal price trends are investigated, as well as the availability of final destinations for sorted waste flows (Table 1)<sup>2</sup>. More detailed, investigated scrap metal price trends were: slight volatility trend (the market prices for sorted metals and vehicle hulks slightly change at [-2.50; 2.50] %/year value interval), moderate growth trend (the price values increase at [2.51; 5.0] %/year value interval) and strong growth trend (the price values increase at [5.01; 15.0] %/year value interval). Additionally, to account for the dynamics of various modelling parameters, long-term planning horizon is divided into two periods, each having a time interval of one year.

Optimal decisions for all created test problems were solved using the LINGO 13.0 solver on a Toshiba Qosmio with an Intel Core i5-430 M mobile

technology processor. The CPU times for all test problems varied from less than one second to several seconds.

**Table 1. Overview of created test problems**

Test problem	Scenario	Availability of thermal treatment entities	
		ATT plant	Incinerator
1	Slight volatility trend	Unavailable	Unavailable
2		Unavailable	Available
3	Moderate growth trend	Unavailable	Unavailable
4		Unavailable	Available
5	Strong growth trend	Unavailable	Unavailable
6		Unavailable	Available

Profits per ton of processed vehicle hulks and recycling, recovery, and energy recovery efficiencies of the optimal decisions for the 6 test problems are summarised in Table 2.

**Table 2. Case study profits and eco-efficiencies**

Test problem	Algorithm solution	Profit	Recovery rate (%)	Recycling rate (%)	Energy recovery rate (%)
1	The best	306.86	82.96	82.96	0.0
	The worst	106.13	82.96	82.96	0.0
2	The best	312.45	92.94	82.96	9.98
	The worst	106.13	82.96	82.96	0.0
3	The best	315.22	82.96	82.96	0.0
	The worst	129.39	82.96	82.96	0.0
4	The best	320.81	92.94	82.96	9.98
	The worst	129.39	82.96	82.96	0.0
5	The best	388.57	82.96	82.96	0.0
	The worst	115.49	82.96	82.96	0.0
6	The best	394.30	92.94	82.96	9.98
	The worst	115.49	82.96	82.96	0.0

Analysis of the financial results of the projected vehicle recycling factory shows that the lowest profit of [106.13; 306.86] €/tonne of processed vehicle hulks was made in the first test problem (when scrap metal prices showed slight volatility trend and there was no possibility for waste incineration), and the highest profit of [115.49; 394.30] €/tonne of processed vehicle hulks was made in the sixth test problem (when scrap metal prices showed strong growth trend and waste incineration was a viable option). Such a result is a direct consequence of the sixth test problem predicting a far more suitable trend in scrap metal prices change. In addition, it should be mentioned that a higher value of the right profit bound was made in test problems which allowed incineration of isolated waste (i.e. the best solutions of test problems 2, 4 and 6), because in that situation incineration presents a financially more favorable destination for isolated waste materials. Availability of incinerator (MSWI and/or cement kiln incinerator) did not influence calculations of the worst solution of test problems 2,

<sup>2</sup> Due to page limitation data used in this numerical study is not presented. All data is available upon request.

4 and 6, because then land-filling is more cost-effective than incineration.

Regarding the eco-efficiency, recovery and recycling rates were 82.96%, except in the situations when it was possible to incinerate isolated waste and decision making was optimistically oriented. More detailed, when the best solution of test problems 2, 4 and 6 were explored, it was found that recovery rate and recycling rate were increased to 92.94% and 9.98% respectively (Table 2).

As for the inventory management, their level was during entire testing equal to the safety inventory level. In addition, it has been identified that vehicle recycling factory favours the approach of ordering the exact quantities of hulks that can be processed, which clearly indicates their intention to avoid unnecessary costs for storing excess hulks.

Regarding the sorting decisions, it has been clearly identified that the vehicle recycling factory aims at reaching the highest possible level of quantity and quality of sorted metal flows, regardless of the value of eco-efficiency quotas. Both ASR fractions are always mechanically recycled, primarily in order to isolate valuable non-ferrous metals. The Al-rich fraction is always additionally purified, because the additional income always exceeds the costs of its sorting.

## 5. CONCLUSION

The formulated model can reduce the risk of uncertain situations in the projected Serbian vehicle recycling system (Fig. 1). It provides optimal solutions to fully interval ELV recycling planning problem which helps the recycling managers to analyze economic activities and to arrive at the best decisions. More detailed, it useful for creating optimal long-term plans for procuring vehicle hulks, sorting generated material fractions, allocating sorted waste flows and allocating sorted metals.

Presented model can be of assistance not only to domestic ELV recyclers, but also to our policy makers in order to analyse the Serbian ELV Ordinance influence on vehicle recycling industry behaviour.

Future research will focus on more extensive testing of the proposed model and creating strategic production guidelines for Serbian vehicle recycling

system, and making capacity strategies for all waste entities.

## ACKNOWLEDGMENT

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# IMPORTANCE OF EXPLOITATION PARAMETERS RELATED TO RETREAD TIRES OF COMMERCIAL VEHICLES

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**Abstract:** *Most of the problems of waste treatment have not been solved and they are becoming more important every day, regarding its environmental, economic and other aspects. There is a special category of waste consisting of spent / used tires. One of the ways to treat them in order to allow tires to be reused on vehicles is retreading. This process, applied around the world and in our country, has a number of positive effects on the environment, logistics costs, etc. The practice has shown that successful use of retread tires depends on the type of tire, vehicle, etc., but also on the manufacturer. This paper has treated the most important exploitation parameters, based on a real sample of used tires in one of the units of GSP Belgrade, which can be used for the selection of manufacturers.*

**Keywords:** *tire retreading, exploitation parameters, used vehicles.*

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## 1. INTRODUCTION

There is huge number of vehicles and its parts on the market, and every production and exploitation generates certain expenses. When speaking about tires, big transport systems, especially commercial vehicles, often use retreading (process in which tire with worn tread is putting back into function). This is consequence of price and exploitation of tires, since they are constituent parts of all vehicles – from passenger vehicles to heavy loads trucks, planes, industrial vehicles etc. Several experiences are met dealing with exploitation of retreaded tires. When making decision about tire manufacturer, main criteria/parameters are number of tire retreads, travelled distance, and also expenses for travelled distance for new tire and retreaded tire. Safety is factor is also present and literature shows that safety level of correctly retreaded tire is not declining in comparison to new one (Hammond at al. 2009).

Having above mentioned in mind, this paper aims to „help” big transport systems by choosing exploitation parameters of tires for making decision which manufacturer to choose. Input parameters (based on which such decisions are made) are gathered by analysis of real sample of used tires from one section of biggest company for public transport, GSP Beograd. For that reason, this paper has 4 parts. First part contains introduction and also present problem and aim of the paper. Second one

gives short description of retreading and third part gives an overview of used literature based on which the orientation to deal with problem of choosing tires manufacturer is created, based on conditions and parameters of exploitation. Fourth, key part contains analysis of important parameters of exploitation of used tires – number of retreading and travelled distance by tire, as key parameters for making decision from which manufacturer should one company buy the tires. When choosing manufacturer, besides mentioned parameters it is also necessary to analyse environmental and economical aspects of using retread tires. Fifth part presents conclusive consideration of these, and potential further researches in this area.

## 2. ABOUT RETREADING

Retread is process that has increased usage for tires of commercial vehicles, but lately also for tires for passenger's vehicles. There are many reasons for that. One of main is that retreaded tire can be compared to new ones by technological-exploitation characteristics, with significant economical and ecological effects (Figures 1 and 2).

Tires got this way are cheaper from new one with equivalent standard and similar quality; money saving level is about 45%, retread tires have huge impact on surroundings – only 5l of fuel is used for tire retreading process instead of 35l used to produce new one (<http://www.spiegel.de/auto/werkstatt/a->

169203.html (accessed 25.11.2011.)). Importance of retreading results that it became also an industrial process (Figure 3).



Figure 1. Landfills tires in Rakovici (part of the city where the most disposed tires) (Photo documentation "Politika", accessed 21.08.2012)



Figure 2. The fire at the landfill tires in Jagodina 11.04.2012. (Photo documentation "Blic", accessed 21.08.2012).

Demand for retread is created when tread is worn (cross section of typical tire is given on Figure 3), meaning that depth of channel of tread is lowered to allowed minimum. If according control determines that construction of other parts of tires is acceptable, he is sent to be retread in order to prolong its exploitation.

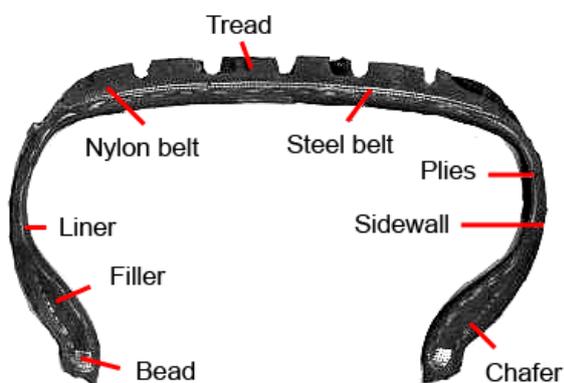


Figure 3. Typical structure of tire (cross section)

There are two basics process of tire retreading most used in praxis, so called cold and warm retreading [8]. Process of *cold retreading* is based on placing tread – already prepared warmed ring or

proper length of tape of tread – on processed surface of „old“ tire (Figure 4a, 4b). New tread is glued to tire on temperatures below 100°C in special chambers. Retreading has no impact on tire structure, so that this procedure can be repeated several times on same tire and is common for retreading tires for commercial vehicles.



Figure 4. Types of treads - (a) ring shape, - (b) strip shape

*Warm retreading* is process is when prepared ring or proper size of tape of tread is put on tire in proper press and is heated to temperature of about 140°C. Due to high temperature, one tire can be retreaded only once, so this process is suitable for retreading tires of passenger's vehicles.

In literature almost doesn't have any papers dealing only with tire retreading, especially ones related to decision making for their exploitation. This is opposite to mass usage of retreaded tires, and present problems from this area, which was the reason to deal with by authors of this paper. For example, in praxis one of frequently asked questions is whether retreading and number of retreadings are useful. Answer to this question should include expenses of tire retreading, but also of their exploitation. Especially, that has to be considered having in mind that costs of tires are one of the biggest exploitation expenses of commercial vehicles [8], [2].

### 3. LITERATURE REVIEW

Due to overview mention problems, hereby follow short overview of papers related to ELV treatments and its parts. Practice has shown that these two classes of problems are tightly connected and it is not common to treat them separately. The first class of problems is related to all the activities performed on vehicles which have finished their working life and cannot be reused (or at least some of their parts, among which are the tires). This class concerns problems related to the influence of used vehicles on the environment, issues concerning the industry of disassembling of used vehicles, including those concerning technical-technological treatment of almost each part of a disassembled vehicle, as well as the problems related to the further exploitation of such parts. The second class contains the location-routing problems. All the problems

related to the location of facilities for treatment of described parts and complete ELVs are included in this class of problems.

Froelich at al. (2007) points out the importance of choosing the highest possible quality materials for manufacture of different parts of vehicles, which is also important from the aspect of ELV treatment [7]. When speaking about retreading tires, this could be the basis for making their return into re-usage more simple. The so-called Mexican model [3] by Cruz-Rivera and Ertel (2009) deals with the problem of collecting used parts of ELV and increasing the percentage of use of those parts. Some of the proposed solutions could be used when speaking about retreading tires. Le Blanc at al. (2006) have considered problematic of collection of ELVs in the Netherlands [10]. The authors have examined the ELVs treatment, without paying special attention to the used tires. Regarding the logistics aspect of ELV treatment, Dabic and Miljus (2007) [4] suggest a specific solution which might be applied to the tires with old and used treads. Dabic and Miljus (2008) have examined the treatment of used tires in general and proposed a model for location of facilities for their treatment [5].

#### 4. IMPORTANCE OF SOME EXPLOITATION PARAMETERS OF TIRES FOR PROCESS OF THEIR RETREADING

Retreading is one of the methods to treat tires in exploitation with aim to prolong their work/life duration. Related to that, procedures of improving of retreading management and technology of this procedure are present (also seen as part of industrial treatment). At the same time, validity of this treatment is being permanently tested and proved, both from economical and ecological aspect, which is significant for tire manufacturers and their users (especially for big transport companies).

When analysing profitability of tire retreading, not only expenses and saving when realising this industrial-logistic process are calculated. Here are numerous parameters related to all that was happening with tire during its exploitation till the end of work life, when tire is written-off. Some of parameters are number of tire retreading, travelled distance of tire (new, after each retreading, total distance), exploitation conditions (load/speed of vehicles, road type where vehicle is driven on, driving style etc.). Also, one of important parameters/information is which company produce tires (Figure 5a and 5b (<http://teretnavozilacom/smf/tehnika/protekt-guma-postupak-i-opceno-o-njima-3336/> accessed 08.09.2012)).



Figure 5a. Part of the plants for retreading

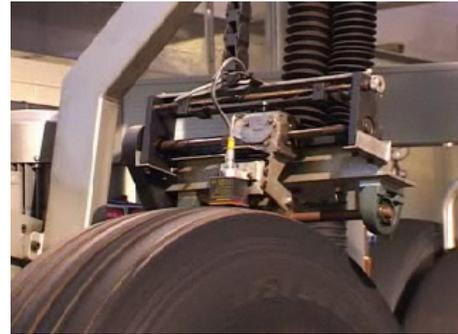


Figure 5b. Part of the plants for retreading

When the tread of a tire is obsolete or damaged, the decision related to its next retreading or dismiss should be made. In their paper, Beukering and Janssen (2001) assume that retreaded tires travel the same distances as the new ones. Ferrer (1996) presumes that service life of a tire does not depend on the number of retreading operations. However, the research made for this paper has shown that the travelled distance of a tire is reduced with every retreading procedure and that total number of retreading operations also depends considerably on the manufacturer – it is not unlimited. In that case, there are two important issues, the first one related to the number of retreading by that moment and the second one concerning the travelled distance during the exploitation. It can be assumed that these two parameters are random values, since they depend on a number of factors (manufacturer, driving conditions, road quality, type/load of vehicle, mode of driving etc.). In order to check this assumption, a detailed analysis of significant sample of written-off bus tires in one of the facilities of Public Utility City Transport Company “Beograd” (the biggest company for public city transportation in Serbia) has been done for two manufacturers – „Sava“ and „Kormoran“.

In this paper, analysis includes three key parameters for making decisions on choice of tire manufacturer whose retreading is expected during exploitation in transport company:

- a) Number of retreading made on each of tire from sample to its writing-off

- b) Total travelled distance by each tire in function from number of retreading to its writing-off
- c) Partial travelled distance after each retreading

a) What is characteristic for tire exploitation is the fact that buses of vehicle fleet connects central area of town with its suburb. Those vehicles are running on damaged roadway. Results of analysis of number of tire retreading (till writing-off) of two manufacturers (507 tires „Sava“ i 547 tires „Kormoran“ which are dominant in structure of used tires in this department), are given on Figures 6a and 6b.

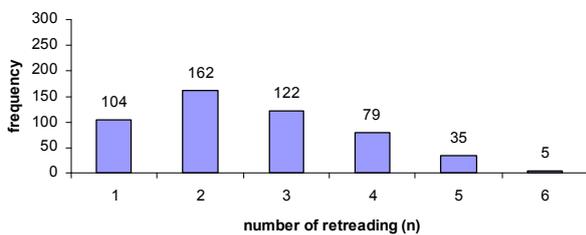


Figure 6a. Empirical distribution density of total number of retreading (till writing-off) on analysed sample of tires „Sava“

Based on the values from the Figure 6a, it can be noted that the number of retreading of “Sava” tires is a random value with mean  $\mu_{Sava} = 1.59$  (retread/tire). The hypothesis on accordance of described empirical distribution with the Poisson probability distribution law is confirmed by the Chi-squared test ( $\chi^2 = 2.227$ ).

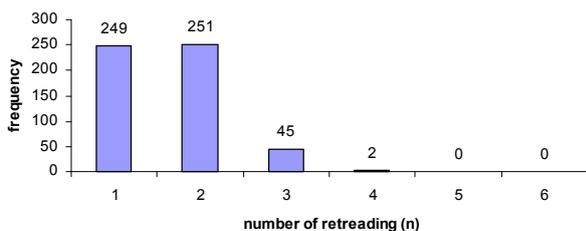


Figure 6b. Empirical distribution density of total number of retreading (till writing-off) on analysed sample of tires „Kormoran“

For “Kormoran” tires, significantly different distribution of retreading per tire is noted (Figure 6b). Mean value is  $\mu_{Kormoran} = 0.63$  (retread/tires), while the hypothesis on accordance of described empirical distribution with Poisson probability distribution law has not been confirmed. This shows a significant difference between the exploitation parameters of those two manufacturers. Also, it should be emphasized that there are cases where a new tire, due to some damages, cannot be retreaded (in Figure 6a and 6b these are the frequencies for

values of random variable equal to 0). For “Sava” tires this probability is  $p_{0, Sava} = 104/506 = 0.206$ , and for “Kormoran” tires  $p_{0, Kormoran} = 249/547 = 0.455$ .

b) One of the basic starting parameters for choice of tire manufacturers is total travelled distance by each tire till writing-off (travelled distance of new + distance travelled of retreaded tire). Analyses of mean travelled distance values show high correlation coefficient (above 0.98) with assumed linear trend (Figure 7).

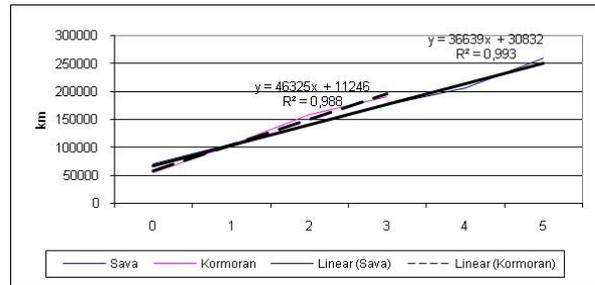


Figure 7. Trend lines representing the sum of the total travelled distances in function of number of retreading for “Sava” and “Kormoran” tires

Decision making about retreading of tires based on these analysis is not always reliable. The answer to this question based on the presented distributions and diagrams can be hardly gained. Namely, in a particular case it is not known what happened with certain tire, or in other words, how the “history” of its exploitation may influence its future behaviour. It is noted here that, due to characteristics of the analysed parameters, the results for “Sava” tires will be used in the rest of this paper.

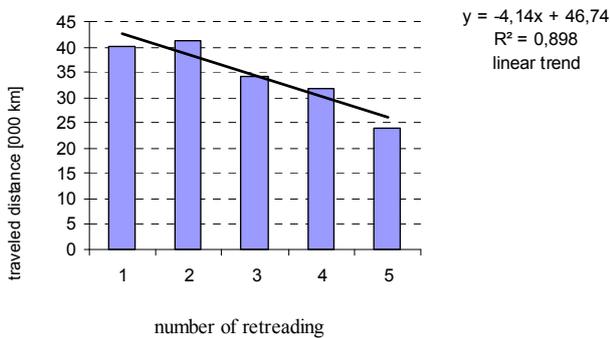
c) Partial travelled distance after each retreading of one tire is also important parameter for making decision both about manufacturer and retreading itself. As „Kormoran“ tires are dominantly retreaded only once, this paper gives results (average values) only for „Sava“ tires (Table 1 and Figures 8 and 9).

Table 1. Partial distance travelled after each retreading

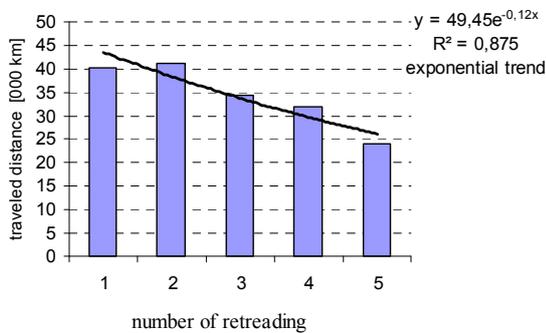
(n) number of retreading of „Sava“ tires	Average distance travelled by tire in function (n) in 000 km
1	40.2
2	41.1
3	34.3
4	31.9
5	24.1

In Table 1 it can be seen the rule - with increase of number of retreading, travelled distance by tire after each retreading decrease (also we can see small deviation after second retread). In order to research this parameter, analysis of trends which describes this relation was made. It was noted that linear trend ( $R_L$ ) and exponential trend ( $R_e$ ) describe this

connection with almost the same correlation ( $R_L = 0,9$  for linear trend and  $R_e = 0,88$  for exponential trend) – Figures 8 and 9.



**Figure 8. Dependence of distance travelled by tire on number of retread – linear trend**



**Figure 9. Dependence of distance travelled by tire on number of retread – exponential trend**

Trends shown point high correlation of both functions, and choice could depend on eventual further analysis. Functions gained this way can be useful for making various decisions: whether to do or not retreading on one tire, choice of tire manufacturer, and usage of tire respecting driving conditions etc.

## 5. CONCLUSION

Tire retreading presents important ecological and economical problem which is not simple to solve. Special importance of making decision for one transport company whether to buy new tires or to retread used one. To make such decision, it is important to know exploitation parameters of tire, where the accent is put on distribution of probability of number of retreading and travelled distance after certain (number) of retreading. Aiming this, sample of tires of vehicle fleet of biggest company for public city and suburb transportation in Belgrade was analysed. Results point to important stochastic level of these parameters and important level of correlation between them.

To make final decision to retread or not, it is necessary that for each such problem proper data

bases for each tire are provided and statistic analysis are made. It is also necessary that data are separated for each department, for homogeneous group of tires and vehicles, exploitation conditions etc. Of course, these analysis/results have to include homogeneous of exploitation conditions – regime of their exploitation. Only by that, one big transport company which chooses to use retreaded tires can provide quality parameters and based on them makes correct decision if and when retreading, as one modern industrial and logistic process, is justified.

## ACKNOWLEDGMENT

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## LOGISTIC CENTERS IN SUPPLY CHAINS: A DISTRIBUTION SYSTEMS DESIGN PROBLEM

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***Abstract:** Globalization, competitiveness in global markets and products with short life cycles, have significantly increased cargo flows. Facilitation of these flows in an efficient and cost effective way represents one of the biggest challenges for the logistic systems. This primarily implies finding an optimal location of objects that are part of the logistic systems. The location problem considered in this paper concerns the optimal number, type, size, location and allocation of logistic centers in distribution systems. To solve this problem, a mathematical model for the optimization of the distribution systems, based on an expanded capacity-limited fixed cost location allocation model on a network has been developed. Alternatively, genetic algorithm has been developed and recruited to seek for the appropriate solution of the model. The effectiveness of the proposed approach is evaluated with a numerical example of locating international logistic centers in the Republic of Serbia.*

***Keywords:** distribution systems, location problems, logistic centers.*

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### 1. INTRODUCTION

In today's global and competitive business environment, efficiency of logistics operations has become one of the most powerful weapons for winning the leading positions on the market. It is therefore of fundamental importance to optimize the flows of goods among suppliers, distributors, and customers by designing optimal distribution system. Distribution system design problems consider determining the best way to transfer goods from the supply to the demand points while minimizing the overall costs. They involve strategic decisions which influence tactical and operational decisions and affect the cost of the distribution system and the quality of the customer service level. One of the most important strategic decisions at designing a distribution system and optimizing a supply chain is to find an adequate location of objects that are part of the system. Optimal locating of objects in relation to existing or expected material flows represents a prerequisite for the optimization of the overall distribution system and a basis for making appropriate tactical and operational decisions.

In this paper, a location problem of logistic centers in a distribution system was investigated.

This type of the problem has been investigated by Taniguchi et al. [10]. Nozick and Turnquist [8] were dealing with locating distribution centers for automotive industry. Klose and Drexler [5] gave a good overview of the developed mathematical models for solving location problems in distribution systems. Melachrinoudis and Min [7] were dealing with the problem of redesigning a network of distribution warehouses. Yang et al. [12] investigated locating of distribution centers using fuzzy logic.

In order to solve the problem, an expanded capacity-limited fixed cost location allocation model on a network has been developed. Capacity-limited models imply solving a facility location problem in which facilities have constraining capacities on the amount of demand they can serve. These types of problem have been investigated by Zhou and Liu [13] and Rodriguez et al. [9].

The fixed costs approach considers locating facilities on a network while taking into account the capacity of the facility and costs for its locating. The objective of this approach is to minimize total facility and transportation costs, determining the optimal number and locations of facilities, as well as the allocation of demand nodes to a facility. This

approach has been investigated by Balinski [1] and Current et al. [2].

In this paper, the problem of distribution system design was to locate one or more logistic centers on the existing transportation network needed to cover the entire demand for logistics services in a defined catchment area. The centers are expected to satisfy high level of logistics service quality criteria. In order to solve the problem, a mathematical model was developed. The model enables determining optimal number, type, size and location of logistic centers, as well as the allocation of customers to the located centers, while seeking to minimize total distribution costs of considered cargo flows. Additionally, the model determines the optimal transport mode for transporting particular cargo flows between each two pairs of origin and destination nodes, taking into account the planned or allowed share of available transport modes on the network. Also, it has a specific approach at determining the optimal capacity of located centers, by considering fixed operating costs of the center in addition to the investment costs related to locating a center at the location.

The developed model was tested in the numerical example of locating logistic centers of international importance in the Republic of Serbia. The location problem of intermodal terminals and logistics centers in Serbia has been previously addressed in the project IMOD-X (Intermodal Solutions for Competitive Transport in Serbia), as well as in Vidovic et al. [11] and Georgijevic et al. [4].

The paper is organized as follows. In Section 2 the defined distribution network design model is introduced. Section 3 provides an overview of the considered numerical example as well as the obtained computational results. Section 4 contains some conclusions and future research directions.

## 2. MATHEMATICAL MODEL

In order to model the location problem of logistic centers in a distribution system, the following notations for the parameters are introduced:

$i \in \{1, 2, \dots, I\}$  is the index for supply nodes on the network;

$j \in \{1, 2, \dots, J\}$  is the index for logistic centers potential location nodes;

$k \in \{1, 2, \dots, K\}$  is the index for demand nodes (customers) on the network;

$t \in \{1, 2, \dots, T\}$  is the index for modes of transport;

$n \in \{1, 2, \dots, N\}$  is the index for logistic centers types;

$w_{ik}$  – cargo flows generated in supply node  $i$  that have destination in the demand node  $k$ ;

$p$  – max number of centers to be located in order to cover total demand;

$S_j^n$  – capacity of the logistic center of a type  $n$  located in node  $j$ ;

$c_j^n$  – investment costs related to locating a logistic center of a type  $n$  in node  $j$  per unit of capacity;

$f_j^{fix}$  – fix costs of the center located in node  $j$  per unit of capacity;

$f_j^{var}$  – variable costs of the center located in node  $j$  per unit of cargo flows handled;

$d_{ij}^t$  – distance between the nodes  $i$  and  $j$  by the transport mode  $t$ ;

$d_{jk}$  – distance between the nodes  $j$  and  $k$ ;

$\alpha^t$  – transport costs per unit of cargo flows and unit of distance between the nodes  $i$  and  $j$ , in relation to the used mode of transport  $t$ ;

$\beta$  – transport costs per unit of cargo flows and unit of distance between the nodes  $j$  and  $k$ ;

$M^t$  – max share of the transport mode  $t$  in total realized transport.

Decision variables are defined in the following way:

$$Y_j^n = \begin{cases} 1, & \text{if center of a type } n \text{ is located in node } j \\ 0, & \text{if center of a type } n \text{ is not located in node } j \end{cases}$$

$X_{ijk}^t$  – fraction of flow from the supply node  $i$  to the destination node  $k$  routed through the logistic center located in the node  $j$  by the transport mode  $t$ ,  $0 \leq X_{ijk}^t \leq 1$

The defined mathematical model of the location problem:

$$\begin{aligned} \min F = & \sum_{t \in T} \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \alpha^t d_{ij}^t w_{ik} X_{ijk}^t \\ & + \sum_{j \in J} \sum_{n \in N} (c_j^n + f_j^{fix}) S_j^n Y_j^n \\ & + \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \sum_{t \in T} f_j^{var} w_{ik} X_{ijk}^t \\ & + \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \sum_{t \in T} \beta d_{jk} w_{ik} X_{ijk}^t, \end{aligned} \quad (1)$$

subject to:

$$\sum_{j \in J} \sum_{n \in N} Y_j^n \leq p \quad (2)$$

$$\sum_{n \in N} Y_j^n \leq 1 \quad \forall j \in J \quad (3)$$

$$X_{ijk}^t \leq \sum_{n \in N} Y_j^n \quad \forall i \in I, \forall j \in J, \forall k \in K, \forall t \in T \quad (4)$$

$$\sum_{t \in T} \sum_{j \in J} X_{ijk}^t = 1 \quad \forall i \in I, \forall k \in K \quad (5)$$

$$\sum_{i \in I} \sum_{k \in K} \sum_{t \in T} w_{ik} X_{ijk}^t \leq \sum_{n \in N} S_j^n Y_j^n \quad \forall j \in J \quad (6)$$

$$\sum_{i \in I} \sum_{j \in J} \sum_{k \in K} w_{ik} X_{ijk}^t \leq M^t \sum_{i \in I} \sum_{k \in K} w_{ik} \quad \forall t \in T \quad (7)$$

The objective function (1) enables determination of optimal number, type, size and location of logistic centers, as well as allocation of customers to the located centers, on the defined geographical area for the projected cargo flows, while seeking to minimize total distribution costs. It contains four parts. The first part of the function includes the cost of shipping goods flow from supply nodes to the located logistic centers, taking into account the mode of transport used. The second part of the function considers fixed costs of the logistic centers, including investment costs, taxes, insurance, salaries, etc. The third part considers variable costs of the logistic centers which are directly related to the volume of commodity flows that pass through the centers. The fourth part includes the costs of shipping the goods from the logistic centers to demand nodes (customers).

Constraint (2) allows locating at most  $p$  centers. Constraint (3) ensures that only one center can be located at the node  $j$ . With (4) allocation of demand nodes (customers) is allowed only to the located centers. The complete coverage of demand nodes is fulfilled with (5). Constraint (6) is a capacity constraint assuring that total demand at node  $j$  and demand of all allocated demand nodes do not exceed the capacity of the distribution center located at the node  $j$ . Constraint (7) restricts the maximal share of particular transport modes.

In order to simplify the problem in the model is considered only one type of goods. It is assumed that every supplying node  $i$  is connected by at least one mode of transport with every potential distribution center location  $j$ , as well as that every potential center location  $j$  is connected with every destination node  $k$  by road transport. In order to analyze problems in a more realistic way, the maximal share of a particular transport mode is restricted by the parameter  $M^t$ . To each arc between the nodes are assigned distances  $d_{ij}^t$  and  $d_{jk}$  according to the available transport modes. Transport costs are calculated in dependence of the transport distance between the nodes, quantity of transported cargo and used mode of transport.

The costs of locating a distribution center are defined per capacity unit in dependence of the center type and every particular potential location of the center assuming that different conditions of existing infrastructure at different locations can significantly influence the amount of required investments.

Considering that investment costs per unit of capacity decrease with the increase of capacity, it is to assume that the centers of higher capacity will be selected. However, unused capacity of centers can result with unnecessarily higher operational costs of the centers. In order to avoid the over sizing of centers and therewith increasing operational costs of the centers, within the model the operational costs of a located center are broken down into fixed and variable costs. The fixed costs are the one related to the capacity of a center and include labor costs, taxes, depreciation of infrastructure and equipment, while the variable ones are exclusively related to the amount of cargo flows handled. Besides ensuring adequate determination of centers capacity, breaking down the operational costs enables the measurement of savings in fixed costs achieved by the adequate allocation of demand nodes (customers).

### 3. NUMERICAL EXAMPLE: LOCATION PROBLEM OF DISTRIBUTION CENTERS IN THE REPUBLIC OF SERBIA

The effectiveness of the proposed approach is evaluated in a numerical example of locating logistic centers of international importance in the Republic of Serbia, required to handle distribution of import cargo flows.

Geographically, Serbia represents the shortest road and rail transit route connecting Western Europe with the Middle East. It is crossed by two important European corridors: the road-railway corridor X and the internal waterway corridor VII that are at the same time, the backbone of the Serbian traffic system.

In the example, seven supply nodes, representing the most significant cargo hubs in the region which are handling import flows of Serbia, were analyzed. The nodes are Budapest, Constanta, Istanbul, Thessaloniki, Bar, Rijeka (Koper) and Banjaluka.

The set of customers is defined by 37 demand nodes which represent the most significant economic centers in Serbia: Subotica, Zrenjanin, Kikinda, Vrsac, Pancevo, Sombor, Apatin, Novi Sad, Vrbas, Backa Palanka, Sremska Mitrovica, Ruma, Indjija, Belgrade, Sabac, Loznica, Valjevo, Smederevo, Pozarevac, Kragujevac, Jagodina, Bor, Negotin, Zajecar, Knjazevac, Uzice, Priboj, Cacak, Kraljevo, Novi Pazar, Krusevac, Nis, Prokuplje, Piro, Dimitrovgrad, Leskovac, and Vranje. These selected 37 nodes are a result of the spatial aggregation of demand that was made with the aim to reduce the size of the location problem. Within the example each demand node is viewed as a potential location of a distribution center.

Distances between the nodes in the model represent the shortest paths between the nodes on the real transport networks. Initially defined maximum share of road, rail and water transport is up to 100%, 15% and 15% respectively. Transportation costs between the supply nodes and centers for rail transport are defined on the basis of current official rate for international transport of the Serbian Railways, 0.05 € / tkm. Transportation costs between the supply nodes and centers for road and inland waterway transport are defined on the basis of the current market rates and as defined in Limbourg and Jourquin [6], 0.07 and 0,015 € / tkm respectively.

Distribution of goods from the centers to the customers is assumed to be realized by road transport. The defined distances between the nodes represent real distances on the existing road network. In this example is allowed the distribution of goods to a customer (allocation of a customer to a center) which are at a distance less than 250 km from the located logistics center. The transportation costs of these distribution flows are set to € 0.11 / tkm, based on the current market rates and on the Limbourg and Jourquin [6].

Import quantities/customer demands are derived values based on the official statistics of the Customs Administration Office of the Republic of Serbia for 2012 [3].

The capacities of the distribution centers are assumed to be ranging from 5 to 100 thousand tons, with a step of increase of 5 thousand tons. The required capacities are defined under the assumption that the average handling and holding of every cargo unit in a center will take approximately a week (52 weeks a year). Within the process of handling and holding a cargo, it is assumed that 20 % of the cargo will require placement in racks while remaining 80% of the goods are expected to require block storing, container storing, or bulk storing.

Three types of logistic centers were considered in relation to the modes of transport they could serve: trimodal (IWT - rail - road), bimodal (rail - road) and unimodal (road). Investment value of these centers was defined based on expert's evaluation of investments in land, terminals, manipulative equipment, office building, warehouse and IT systems (this data can be provided by the authors, to interested parties on request). It is assumed that the necessary investments will be covered by a loan, for the time period of 20 years at an annual interest rate of 5%.

The fixed operational costs are set to 25 €/t of capacity and the variable operational costs to 5 €/t of analyzed cargo flows.

The model was tested for the given example by using the software *LP solve 5.0.0.0.* with the following settings:

- Scale type: Geometric, Equilibrate, Integers
- Pivot rule: Dantzig, Adaptive; Max Pivot - 250
- Branch Bound: BB Floor First, AutoOrder; BB Rule - First; Depth Limit: - 50; Obj bound: 1E30.

Additionally, in order to enable eventual testing of the model for greater number of nodes, a genetic algorithm was developed. In order to evaluate the effectiveness of the approach, the model was also tested on the same example with the application of the algorithm and the results were compared with the ones obtained by the *LP solve* software.

In order to examine the influence of number of distribution centers to the design and total costs of the distribution system, the numerical example was tested for cases of setting the maximal number of centers that should be located to 10 and to 3.

### 3.1 Simulation results

The first simulations were carried out by the *LP solve* for the case of locating maximally 10 centers. The best results – the lowest total costs of 357.07 million € per year were achieved for locating 7 distribution centers. The selected locations, capacities and types of centers are given in table 1.

**Table 1. Simulation results – selected types, capacities and locations of centers**

Locations	Capacity in 1.000 t	Type
Subotica	10	Bimodal
Novi Sad	40	Trimodal
Beograd	65	Trimodal
Šabac	15	Unimodal
Užice	10	Unimodal
Kragujevac	30	Bimodal
Niš	15	Bimodal

Allocation of the demand nodes to the selected distribution centers location is shown in figure 1.

The second simulations were carried out by the *LP solve* for the case of locating maximally 3 centers. The lowest total costs, 383.51 million € per year, were achieved for locating 3 logistic centers. The selected locations, capacities and types of centers are given in table 2.

Considering that in this case all demand for logistics services on the defined geographical region has to be carried out by only three distribution centers, the allocation of customers can not be precisely limited, so every of the center partially covers the demand of almost every customer

depending on the supply node and the amount of demand.



Figure 1. Simulation results, allocation of customers to located centers

Table 2. Simulation results – selected types, capacities and locations of centers

Locations	Capacity in 1.000 t	Type
Novi Sad	60	Trimodal
Beograd	95	Trimodal
Krusevac	30	Unimodal

The significant difference in the total distribution costs in the considered cases points out the dominance of the long distance transport costs over logistic centers investment costs.

The selected capacities of the logistic centers, in all analyzed cases (for the defined amount of cargo flows) have an utilization of over 85 % which justifies the particular consideration of fixed logistic centers operational costs in relation to the centers investment costs.

The simulations for both cases were additionally carried out by the developed genetic algorithm. The algorithm provided results in significantly shorter time period but were approximately 10 - 12 % diverging from the optimal ones.

Comparison of the results obtained by these two tools is given in table 3.

Table 3. Comparison of the results obtained by the LP solve and by the genetic algorithm

Considered cases	LP solve		Genetic algorithm	
	Total costs in 10 <sup>6</sup> €	Simulation time in s	Total costs in 10 <sup>6</sup> €	Simulation time in s
7 located centers	357.07	3397	404.67	14
3 located centers	383.51	2417	426.79	13

In both cases, by both tools, the same locations of logistic centers were selected as optimal ones, however, there were some divagations regarding the capacities of the centers and allocations of customers to the located centers. Due to that divagations, the simulations using genetic algorithm provided results with higher total distribution costs.

Given that the simulations were conducted for a relatively small number of nodes, the LP solver provides optimal results within a reasonable period of time. Therefore the application of the genetic algorithm is not necessarily required. However, it is expected that, in the case of considering a larger number of nodes, the duration of the simulation in the LP solver will increase significantly due to which the application of the genetic algorithm to solve the problem can be required. In this case, the resulting solutions, regardless of their deviation from the optimum, would be considered as good enough.

#### 4. CONCLUSIONS

Based on the obtained results it can be concluded that the defined mathematical model represents a tool that can be useful in the process of making strategic decisions related to the distribution system design, particularly to the location problems of logistic centers. However, the decision about a distribution system design and location of logistic centers, in real systems, requires considering additional criterias besides the total costs minimization.

Testing of this model on the example of Serbia, came to the following conclusions:

- Dominant role in the total distribution costs of the import cargo flows have transport costs of cargo flows between the supply nodes and logistic centers;
- Simulation results showed that for the same cargo flows on the defined region (for the given input parameters), in the case of locating three centers, the total distribution

costs increase 26.44 million € (about 7 %) in relation to the total cost of the distribution system in the case of locating seven centers;

- In all considered cases, the trimodal logistic centers in Novi Sad and Belgrade were selected as optimal ones.

Given that in this numerical example, a relatively small number of nodes has been analyzed, the LP solver provided the optimal solutions within a reasonable period of time, while the genetic algorithm provided the solutions within a few seconds, but these solutions deviated from the optimal ones for 10 % or more. In the case of using the model to solve a location problem in an environment of much larger number of considered nodes, it is expected that the duration of the simulation using the LP solver would be too long so that the use of genetic algorithm would be needed, and the results obtained by the algorithm would be good enough.

In future research, it would be interesting to investigate the problem by treating some parameters as fuzzy variables, motivated by the uncertainty that often can be associated with parameters such as future customer demands.

## ACKNOWLEDGMENT

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## PACKAGING CHALLENGES AND PROBLEMS IN THE PHARMACEUTICAL COLD CHAIN DISTRIBUTION

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**Abstract:** The global pharmaceutical market is expected to reach \$1.1 trillion USD by 2014. This increase will pose new challenges for logistics. One of the biggest is to deliver several different temperature-controlled drugs. In this process there is a difference between the US and the European regulations. According to the Good Distribution Practice which is used in Europe every digression from the storage temperature should be reported by the distributor and the recipient. This value should be between 2°C and 8°C with drugs which require cooling. However, in the US these kinds of drugs are categorized as a 'Controlled Cold Temperature drugs'. The value of this is also between 2°C and 8°C but allows for differences in temperature between 0°C and 15°C under certain conditions. The Mean Kinetic Temperature (MKT), which is the topic of this paper, is a good opportunity to control the verification process of the packages.

**Keywords:** MKT, cold chain, cooler box.

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### 1. INTRODUCTION

The aim of this article is to present the problems which are caused by the characters of the pharmaceutical logistics in aspect of the packaging technology.

We would like to demonstrate the development opportunities of the packaging which characters very important are, because every product claim different temperature. The packaging must comply to the logistics and also to the strict norms of the pharmaceutical industry, so we are giving an overview on that topic too.

Differences between the U.S. and the European Union's praxis means more opportunities to increase the efficiency of the packaging, than the physical packaging parameter changes. This called the controlled cold temperature and the Mean Kinetic Temperature.

### 2. DESCRIPTION OF THE PHARMACEUTICAL LOGISTICS

The sector's logistics is special, because the long-range surveillance based products strict following-up and the insurance of the just required temperature range. The topic of our presentation is related to the latter, so we would like to give an overview about that first.

The drugs can be grouped into three categories by their storage temperatures:

- 1) The drugs which are in the first group can be stored at Room Temperature, means we can store them between 15-25 ° C.
- 2) The drugs in the next group demand Cool, here between 8-15°C is the proper.
- 3) The drugs which are in the third group give the main theme of this article. These are the drugs which are claimed Cold. The storage temperature of these is between 2-8°C.

During warehousing, these temperature ranges are easy to solve with freeze chambers. But during the transportation and the distribution is not so easy. With cooling chamber transport vehicles and active cool boxes this could be done easily and safely, however it's not economically reasonable. This is why the drug delivery companies have started to be interested about the passive cool boxes.

The passive cool boxes can be applied basically in two way of transportation:

- Long-distance transport
- Distribution

In the first case, there is usually only one opening, like in international shipments. More boxopening have been happened in the second case. So this time obviously the device can provide the

right temperature less time and the operating time is also unpredictable.

In the supply chain, these companies are operated between the factory and the pharmacies. The drugs, required different temperature classes shipped to the warehouse where they are stored properly. By the order of pharmacies they compile the items and deliver them. The application of passive cooler appears in this type of distribution process.

Pharmacies orders small quantities one time, so the active cooling method is no longer economically. The goods are varied, they exchanged rapidly, so pharmacies stores small quantities.

However, the distributor can not go to a shipping address separately with three vehicles each with three temperature ranges, because this drastically increase the freight costs. A van need to serve about 3-5 addresses, so it has to ensure three different temperature ranges at a same time. Due to the small size of the vehicle, here we can not use space separation, which has been already used in the truck. That is why we need to apply passive coolers.

The temperature of the van loading space is between 15-25°C, that is proper for the drugs, require room temperature. The 8-15°C and 2-8°C range should be provided by two differently designed passive cooler. In the next chapter a cooler going to be described, which is applied in daily practice.

### 3. DESCRIPTION OF A PASSIVE COOLER BOX

#### 3.1 The construction of the cooler box

The cooler's size is 520x570x700 mm and it weights 5,65 kilograms. It is based on a five-layer corrugated fiber board box provided with a removable lid. Each side is equipped with a 50 mm thick expanded polystyrene foam insulation. The EPS foam was fastened to the side walls with gluing. In the device the 2-8°C temperature must be provided during the distribution (details in chapter 5.1) with ice accumulators according to the following composition (Figure 1.).

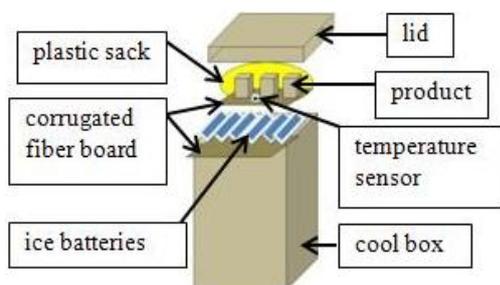


Figure 1. The construction of the cooler box

#### 3.2 Effects of parameters

The operation time of a cooler box is influenced by the following factors:

- number of the placed ice batteries [nr]
- temperature of the placed ice batteries [°C]
- the outside temperature [°C]
- the mass of the delivered products [kg]
- temperature of the delivered products [°C]
- design of the packaging, such as the assembly quality, materials used, geometric dimensions and wall thickness

These factors are not all possible to change, and changing them will not lead to a significant improvement regarding the operational period. According to industry experiences the product which is to delivered, gets into to cooler at a temperature of about 5°C and about 3 kilograms total weight. The number of ice batteries are limited by the box size. Maximum 10 pieces can be placed side by side at the bottom of the box. Based on experience by a validation process, we can say that by increasing ice batteries number the operation time can not be increased significantly. The temperature of the ice batteries are limited by the company used chest freezer's parameters. During the validation process the outside temperature's high influence ability was observed. To know the effects of outer temperature we have to investigate the insulation of cooler box. To solve this using thermal law namely Fourier I. Code of this observation can be easily supported.

#### 3.3 The development of the box with Fourier I. law

According to Fourier I. law (1) the heat flow which is pass through the surface (A):

$$Q = -\lambda A \frac{dt}{dx} = -\lambda \frac{t_2 - t_1}{d} \left[ \frac{J}{s} \right] \quad (1)$$

At the cooler box this wall is consist of several layers of 12 mm paper and 50 mm EPS foam forms. The same temperature passes through at each layers so the following equation can be written [1]:

$$\frac{A_1 \lambda_1 (t_1 - t_2)}{d_1} = \frac{A_2 \lambda_2 (t_2 - t_3)}{d_2} \quad (2)$$

With the sorted equation and substituting the known values and selected the 18°C outside, and the 5°C inside temperature for 1m<sup>2</sup>:

$$Q = \left( \frac{0,047 \frac{W}{mK}}{0,05m} + \frac{0,13 \frac{W}{mK}}{0,012m} \right) \cdot (18^\circ C - 5^\circ C) = 153,05W \quad (3)$$

So that much heat enters to the insulated box through its wall. For example, if we use the same data with increasing the thickness of the EPS foam to 60 millimeters (+20%), we would get 151,02 W so less heat would enter to the box:

$$Q = \left( \frac{0,047 \frac{W}{mK}}{0,06m} + \frac{0,13 \frac{W}{mK}}{0,012m} \right) \cdot (18^{\circ}C - 5^{\circ}C) = 151,02W \quad (4)$$

Our previous statement that with the allowance of the outside temperature the system performance significantly amendable can be verified. Instead of 18°C, we raise this factor also with 20 % which going to be 21,6°C. Substituting this value to the original equation:

$$Q = \left( \frac{0,047 \frac{W}{mK}}{0,05m} + \frac{0,13 \frac{W}{mK}}{0,012m} \right) \cdot (21,6^{\circ}C - 5^{\circ}C) = 195,44W \quad (5)$$

It is worth to compare the solutions:

The 20% thickness increase of the insulation results a 1,3% decrease with the entered amount of heat while the same increasement of the outside temperature caused 20% increasement with the entered amount of heat. It means, that the simple modification of the construction not give quite enough advance. It can be seen that due to the many difference influencing factors there is not a specific formula which properly considers all the effects. By the high variation of parameters and the strict and narrow temperature ranges, required every possible support should be useful. For this purpose we are giving a brief overview on the regulatory system of the pharmaceutical industry.

## 4. REGULARIZATION

### 4.1 Regulatory systems

There is not just one 'supreme' regulatory system that would give specific instructions about the unabrogated rules in one particular region.

This fragmentation is evidenced by the following list of the world's largest pharmaceutical markets have regulation appertain to the cold chain [2]:

- The EU Guide to Good Manufacturing Practice, Annex 13
- The Guidelines on Good Distribution Practice (GDP) of Medicinal Products
- CDC Guidelines for Maintaining and Managing the Vaccine Cold Chain
- WHO Guidelines on the international packaging and shipping of vaccines

- PDA Technical Report 39
- The US Code of Federal Regulations
- US and European Pharmacopoeia [2]

Applying to the temperature ranges which is the topic of this presentation in Hungarian practice The Guidelines on Good Distribution Practice (GDP) of Medicinal Products is used, which include the following:

*„If a deviation such as temperature excursion or product damage has occurred during transportation, this should be reported to the distributor and recipient of the affected medicinal products. A procedure should also be in place for investigating and handling temperature excursions.” [3]*

In contrast, the United States Pharmacopoeia, in the General Notices and Requirements, defining a transition temperature range, it is known as Controlled Cold Temperature.

### 4.2 Controlled Cold Temperature and The Mean Kinetic Temperature

*“Controlled cold temperature” is defined as temperature maintained thermostatically between 2°C and 8°C (36° and 46°F), that allows for excursions in temperature between 0°C and 15°C (32° and 59°F) that may be experienced during storage, shipping, and distribution such that the allowable calculated mean kinetic temperature is not more than 8°C (46° F). Transient spikes up to 25°C (77° F) may be permitted if the manufacturer so instructs and provided that such spikes do not exceed 24 hours unless supported by stability data or the manufacturer instructs otherwise.” [4]*

The Mean Kinetic Temperature (MKT) which is used in the definition is defined in the International Conference on Harmonization (ICH) Q1A(R2) document as:

*“A single derived temperature that, if maintained over a defined period of time, affords the same thermal challenge to a drug substance or drug product as would be experienced over a range of both higher and lower temperatures for an equivalent defined period. The mean kinetic temperature is higher than the arithmetic mean temperature and takes into account the Arrhenius equation.” [5]*

*„The use of MKT to represent the expected impact of temperature variations on the quality of a drug product.” [6]*

The transformed formula is the following:

$$MKT = \frac{\Delta H/R}{-\ln \left( \frac{e^{-\frac{\Delta H}{RT_1}} + e^{-\frac{\Delta H}{RT_2}} + \dots + e^{-\frac{\Delta H}{RT_n}}}{n} \right)} \quad (6)$$

where:

$\Delta H$  = the heat of activation for the degradation reaction; assumed to be 83,144 kJ per mol unless more accurate information is available from experimental studies.

$R$  = the universal gas constant,  $8,3144 \times 10^{-3} \left[ \frac{\text{kJ}}{\text{molK}} \right]$

$T_1$  = the average temperature, during the 1st time period [K]

$T_2$  = the average temperature, during the 2nd time period [K]

$T_n$  = the average temperature, during the nth time period [K]

$n$  = the total number of temperatures recorded. Note that the interval between temperature measurements is assumed to be identical.

The activation energy  $E_a$  is assumed to be 83.144 kJ/mol. This value has been derived from evaluating published data for more than 100 chemical substances, namely small molecules that are commonly used as active ingredients in pharmaceutical products, and calculating the mean. „If feasible, and definitely in case of biological/biotech products, it is advisable to use the actual activation energy found for the particular substance instead of the mean value. The actual activation energy can be derived by calculating the intercept of the Arrhenius plot with the y-axis.” [7]

## 5. APPLYING THE MKT IN THE DAILY PRACTICE

### 5.1 The validation process of a passive cooler

One passive cool box which is applied to insure 2-8°C range and used in every day practice has been introduced in the chapter third. The operation period have to be determined by a validation process.

8 pieces underneath ice batteries reached 8°C after 616 minutes. During the validation in the first six hours the box and the bag was open for 1-1minute once in every hour simulating a take out of a product, and after the sixth opening we let it closed till 18 hours.

According to the original idea the cooler box would have to provide the appropriate temperature range for 24 hours, that is why there was an

investigation on the impacts of the influencing factors in the second chapter. During the test, the average outside temperature was 17,7°C, which is closed to the allowed 15-25°C, so we can not increase the performance of the box by this solution. To solve a small structural change is needed on the box, in according to the required thermodynamic laws.

### 5.2 Modification of the cooler

It is a well known context that the warm air raises, cold air moves into position.

So it means that in the original assembly the bottom placed ice was cooled just partly of the products, and mainly the bottom of the box. After the modification of the cooler, the ice batteries placed below the lid, over the products in a 4 points fixed netbag. The netbag also can be closed, so after the transportation the ice batteries can be managed by boxgroups, not by piece by piece so they can be re-freezable. Because of the frequent product pull out, the fixation has to be easily soluble and it also has to be easy to fix. The task has been by the following manner (Figure 2.):

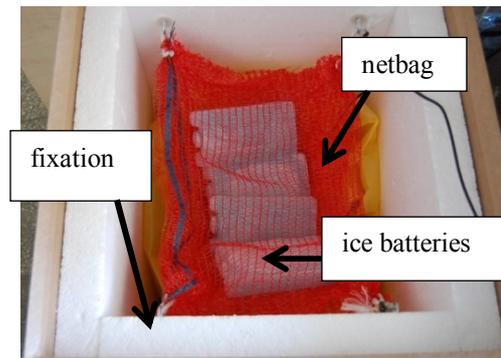


Figure 2. Placement of the ice batteries

It can be seen that the courier can easily unhang it from one side to the opposite and put it back after removing the goods.

With this setup, a new measurement was performed. We have applied just 6 pieces ice batteries because we have to decrease the cost, and to investigate the new construction. 6 pieces ice batteries were placed above the products, apart from that the test was the same as the previous one. After 992 minutes, the inside temperature of the cooler box exceed 8°C. Therefore with less ice batteries this system assured the proper temperature 6 hours longer than the previous one. Another advantage may can be that all of this was reached at 20,3°C outside average temperature, which means nearly 3°C higher temperature, comparing to the previous measurement. It could even be cost-saving factor, as it is not unimportant because of the fuel costs,

considering that in a summer day how much the interior of the transport vehicle has to be cooled, comparing to the surrounding temperature. The exact definition of this is beyond the topic of this article, therefore it is not discussed in detail here, but it can be treated as an advantage.

### 5.3 Analysis of measurements

The interesting was that the excursions was just after 24 minutes after the starts, when the temperature went lower under limit (2°C).

According to The Guidelines on Good Distribution Practice (GDP) of Medicinal Products, which was presented among the regulation systems it should not be used in the European practice. If we take a count about the advantage of this modification, we can see that applying the American options can be a possible solution. The American options namely are the Controlled Cold Temperature and the MKT.

According to the original idea, analyzing the measurement results in 24 hours, the lowest temperature was 0,9°C and the maximum was 8,7°C, so it is in the controlled cold temperature range (0-15°C). So the MKT can be applied. During the measurement the temperature changed in every minute, so we choose one minute to be one period. Substituting to the formula:

$$MKT_1 = \frac{83,14472/0,008314}{-\ln \left( \frac{e^{-\frac{83,14472}{0,008314 \cdot 290,45}} + \dots + e^{-\frac{83,14472}{0,008314 \cdot 281,85}}}{1440} \right)} \quad (7)$$

$$MKT_1 = 7,4^\circ C$$

Therefore, the effect of temperature fluctuations occurring during the 24 hours is the same, as, if the product had been stored at 7,4°C for 24 hours. The number of intervals can be reduced, if we select one hour as a period and the value of these will be the average of the temperatures which are changing in every minute. Thus,  $MKT_{60}$ 's value is 7,3°C. [8]

The temperature stayed within the allowable range, with both of the counting methods, so according to the American regulatory system that could be used in everyday practice with the modified cooler box design. We summarized the measurements results in the following table (Table 1.).

## 6. CONCLUSION

In this presentation, we demonstrated that the use of passive cooling box is unavoidable for the economical delivery of the products.

We demonstrated that the development possibilities of the device is significantly limited, so in a dynamic, large-scale, highly regulated market such as the pharmaceutical industry, every reliever, cost-cutting option is required.

**Table 1. Comparative table of measurements**

Ice batteries	Pieces	8	6
	Location	bottom	above
Operation time [min]		617	992
Temperature in the van [°C]		17,7	20,3
Calculated temperature with MKT after 24 hours [°C]		8,9	7,4
Cost of cooler box [€]		38	36
Applicable without MKT		yes	no

Such a helpful option can be to extend the strict, narrow temperature ranges, bearing in mind, of course, to preserve the quality of the products. Suitable for that for example the MKT defined by the ICH and the Controlled Cold Temperature which is used in the USA.

The permit of the MKT and Controlled Cold Temperature the drug delivery companies could be applied new packaging devices in Europe, too.

Very important expectations of these new packaging is to satisfy the logistics requirements. Our demonstrated cool box is a good possibility for this.

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# RELATIONSHIP BETWEEN SUPPLY CHAIN STRATEGIES AND TRANSPORT OUSOURCING GOALS - THE RISK PERSPECTIVE

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***Abstract:** In the literature, the relationship between demand uncertainty and supply chain strategy is well explained. However, although the outsourcing can be the one of the riskiest decision for a firm, this kind of risk is not much explored. Further, the relationship between transport outsourcing and supply chain strategy is still underresearched. The objective of this research is to partly bridge the literature gap and explore the relationship between the reasons for transport outsourcing, and consequently, transport outsourcing risks, and supply chain strategy. The decision about supply chain strategy is strongly related with transport outsourcing decision. We identified and explained two kinds of transport outsourcing risks - external, e.g. supply chain demand risk and internal, e.g. outsourcing contract risk. The result of revealed nature of transport outsourcing risks is a conceptual model which connects supply chain strategies and transport outsourcing goals.*

***Keywords:** Supply chain strategy, Transport outsourcing, Uncertainty, Risk.*

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## 1. INTRODUCTION

Demand uncertainty strongly impacts on supply chain strategy. It should also impacts on transport outsourcing decision. Namely, according to the literature, demand variability impacts on transport fleet size, structure, and utilisation. To improve the transport performances in an uncertain environment, firms usually externalize their transport operations. The main reasons for logistics and, consequently, for transport outsourcing are costs, quality of service and operational flexibility.

In the literature, the relationship between demand uncertainty and supply chain strategy is well explained. However, although the outsourcing can be the one of the riskiest decision for a firm, this kind of risk is not much explored. Further, the relationship between transport outsourcing and supply chain strategy is still underresearched. The objective of this research is to partly bridge the literature gap and explore the relationship between the supply chain strategy and reasons for transport outsourcing, related with risks. Due to a lack of knowledge about given relationship, and, consequently, related lack of empirical research, an exploratory research is used as a suitable research

method to start to explore more in-depth this relationship.

The paper is organized as follows. In the second Section, the main characteristics of modern supply chains and related strategies are briefly overviewed. In the third Section, the impact of time demand risks on the choice of supply chain strategy is explained. In the fourth Section, transport outsourcing and related risks are shown and classified. In the fifth Section, the linkage between supply chain strategies and transport outsourcing goals is shown and explained, while the last Section contains main conclusions and recommendations.

## 2. THE MODERN SUPPLY CHAINS AND RELATED STRATEGIES

Supply chain management (SCM) encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities [1]. It also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and

storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements. It is an integrating function, which coordinates and optimizes all logistics activities, as well as integrates logistics activities with other functions including marketing, sales manufacturing, finance, and information technology.

Some important characteristics of modern supply chains are emphasized in [2]:

- There is no more competition between companies within the supply chain, but between different supply chains;
- The biggest opportunity for costs reduction and/or value increasing lies in partners connection in supply chains;
- The competitiveness of the supply chain is based on the added value achieved by information exchange;
- Competitiveness of supply chains requires joint determination of management strategies
- etc.

Appropriate strategy of supply chain management relies on several key factors [3]:

- Strategy should be adapted to specific requirements of customers;
- Products flow management with stable requirements and reliable supply sources should not be the same as the flows management where the demand is uncertain and source of supply is unreliable;
- The Internet can be a powerful tool for enabling, or supporting the development of specific strategies for supply chain management;
- Management strategies based on the reasoning "the same rule for all" will fail.

A key objective in supply chain management is to shape a chain to meet customer needs and create added value according to given constraints, and among the main constraints is supply chain uncertainty. For these reasons, academics have begun to identify the characteristics of supply chains, to get the better insight into their nature. Two main groups of characteristics determine the nature of supply chain [3] - characteristics of supply and characteristics of demand. Regarding to both of them, stable and evolving, functional and innovative supply chains are identified.

Regarding to the new approach to the supply chain and supply chain management, a literature

began to identify and analyze the various supply chain strategies, mostly during the nineties. The two basic types of strategies are: effective and responsive chains; and the lean and agile chains. Even in the most recent literature, one can notice a little confusion regarding the usage of these terms, and the fact that some authors do not clearly distinguish these two classifications (see also [4]).

### **3. THE RELATIONSHIP BETWEEN TIME DEMAND RISKS AND SUPPLY CHAIN STRATEGIES**

The uncertainty and risks can occur at any point and in any relationship in global supply chains [5]. Therefore, the size and complexity of the supply chains certainly affect the risk increase. The production and/or logistics in global supply chains are often outsourced, which brings many opportunities; it reduces the influence of the demand uncertainty and fixed capital, and supports expansion into new markets. However, outsourcing increases the complexity of the supply chain, because outsourced processes and new participants can be difficult to control, especially in the unknown markets.

Interorganizational networking and, particularly, partnerships with small and medium-sized enterprises (SMEs), increase exposure to risk in large companies [6]. In contrast, SMEs also have their own business risks because of the stronger links with partners in the supply chain (*ibid.*).

The literature body about logistics risks in supply chain is scarce, compared with the one about other supply chain risks [7]. Some authors divide logistic risks, associated with the dynamic characteristics of the supply chain demands, on the risks related with the supply uncertainty and risks related with the demand uncertainty [3]. Consequently, four different types of supply chains were identified: efficient, risk-hedging, responsive and agile supply chains (Table 1).

*Efficient supply chains* use strategies and concepts to minimize activities that do not add value to the product, while using economies of scale and optimization techniques and methods in order to maximize capacity utilization in production and distribution. Developed database and information flows are also used for the same purpose, while the Internet can be a convenient way to achieve integration of information flows. Optimization of production and distribution in this case is performed on the basis of transparent data for demands, capacities and inventories along the supply chain.

**Table 1. Supply chain management strategies classified according to the degree of uncertainty of the processes and customers demand [3]**

		Demand uncertainty (customers)	
		Low (Functional products)	High (Innovative products)
Supply uncertainty (processes)	Low (Stable processes)	Efficient supply chains	Responsive supply chains
	High (Evolving processes)	Risk-hedging supply chains	Agile supply chains

*Risk-hedging supply chains* use strategies and concepts in order to reduce risk to the individual actors. These strategies tend to pull and share resources in chains so that the risks are also shared in case of disruption. Individual participants in the chain can be sensitive to a disruption in supply, but in cases with more than one source of supply, or when there are alternative suppliers, the risk of the disturbance can be reduced. Increasing the level of minimum inventory and sharing the related holding inventory costs with other participants who are also interested to prevent delays in delivery, are the ways to deal with a variety of companies risk management in supply chain. Information technologies, especially the Internet, have a crucial role in ensuring data transparency between companies that share this type of risk. Information on real-time inventory allows the goods movement from one point to another with minimum costs.

*Responsive supply chains* use strategies that increase the reaction time and flexibility of variable and specific needs of customers. The Internet primarily enables defining the exact individual wishes of customers and meeting their requirements in the shortest possible time. One way to achieve this is online ordering, which provides access to the customers and allows 24 hours service seven days a week, as well as the rapid transfer of informations between all stakeholders in the supply chain involved in making product (eg. assembling of ordered computer configuration).

*Agile supply chains* use strategies that aim to be responsive and flexible to the needs of customers, while sharing the risk among all subjects. They actually combine the positive characteristics of responsive supply chains and risk-hedging supply chains. This type is known as agile because they have the ability to respond quickly to changes, diversification and unforeseen customer

requirements, while minimizing the risk associated with fluctuations in various demands, incurred by individual actors in the supply chain.

The interest for risks related with particular supply chains are rapidly rising among researchers (see, for example [8]).

#### 4. MAIN RISKS IN TRANSPORT OUTSOURCING

Although outsourcing may represent the one of the riskiest decision for the company, the literature rarely discusses this type of risk and its reducing potentials [9, 10]. Therefore, modern supply chains are becoming more risky, due to a higher number and complexity of relationships between participants, which may be disrupted or interrupted for a variety of reasons. Along with several other dominant trends in business, the trend of outsourcing, including logistics outsourcing, resulted in gradual development of increasingly complex networks and supply chains [11]. Supply chains grow in length and/or width and a large number of companies are involved in more than one supply chain, thus connecting the supply chains in larger and more complex network structures.

Transport is a function that moves goods from one point to another and so temporally and spatially connecting the different entities in the supply chain. Transport costs can be very significant in the overall cost of the product. For example, the cost of freight transport is equivalent to 6% of gross domestic product in the United States [12]. The importance of transport function is also shown as average transport cost per unit of product. Transport costs account for about 3% of the product price on average [13]. The development of electronic commerce, associated reduction in the average size of shipments and an increase in average number of door to door deliveries, increases the importance of transport costs.

For the purpose of this research, from the viewpoint of transport managers – decision-makers, all transport risks in supply chains are classified as internal and external risks. The internal, or inner risks include all risks related to transport outsourcing decision making: owning own-account fleet, choosing the number of carriers, outsourcing of particular or full management activities, etc. Therefore, internal risks are connected with the relationship carrier-customer of transport services, whereby it sometimes could be the same business entity. The transport service customer usually bears the main risk pressure and responsibility for miscalculations, since he pays for a service, has a

high influence on the usage of available transport resources and directly benefit from the the high quality of transport services.

The external, or outer risks associated with the decision on transport outsourcing include risks related to the dynamic characteristics of the requirements described in the previous section. They may be implied by changing end-user demands, expanding markets or changing the distribution network, by changing the number of participants in the supply chain, the types of relationships between entities, etc.

The risk related to the dynamic characteristics of the supply chain can be reduced by transferring the risk to the logistics/transport provider, or outsourcing. This increases companies flexibility, i.e. reaction time to changing market demands. However, the experiences of the outsourcing decision-making indicate that outsourcing of costs and risks often outsource a competencies and process manageability. Increased risk on opportunity is possible if the company does not manage the outsourcing processes and has not developed mechanisms for decision making on such an important issue [10].

## 5. THE LINKAGE BETWEEN SUPPLY CHAIN STRATEGIES AND TRANSPORT OUTSOURCING GOALS

According to their discussed characteristics, the supply chain strategies can be now interrelated with the main goals of transport outsourcing, in accordance with the related risk classification. Again, the main objectives of transport outsourcing in the literature are costs minimization, increase of transport services quality and adaptation of the company's business strategy. However, there is no available literature that clarify what it means to "adjust the business strategy of the company." Also, there is no available literature that clearly link concepts and management strategies with the outsourcing decisions, and there is no technique, or method of decision making where a particular management strategies are clearly linked to the appropriate outsourcing concepts.

The lack of literature dealing with analysed problem is also identified in [14], where it is emphasized that connection between the strategy of supply chain management and logistics outsourcing is not sufficiently researched.

The main reasons/goals for transport outsourcing are identified in Table 2 and assigned to specific supply chain management strategies. They are in accordance with the goals identified in [10].

The proposed model deals with the combination of uncertainty and, consequently risks related to the outsourcing of transport operations and risks in products supply and demand (Table 1). The degree of uncertainty can be related to the complexity of the process, the state of the transport market and the ability to manage and control outsourced processes.

**Table 2: Linking SCM strategies with the primary goals of transport outsourcing (TO) by using the risk perspective**

		(Transport) demand risks	
		Low (functional products)	High (innovative products)
Transport outsourcing risks	Low	efficiency <b>1. goal: minimization of logistics (transport) costs</b>	responsiveness <b>3. goal: minimization of delivery times</b>
	High	risk-hedging <b>2. goal: minimization of internal TO risks</b>	agility <b>4. goal: Flexibility, minimization of total external and internal TO risks</b>

The presented results could be inspirational for further research about the impact of supply chain strategy on transport outsourcing decision-making. They open the room for both, exploratory and explanatory research in the future and contribute to the normative body of literature on transport outsourcing, which is, actually, scarce.

The proposed model also has a practical value. It could help transport managers in decision-making to identify the best transport insourcing/outsourcing concept for particular supply chain strategy. For that purpose, the proposed model should be used in the very first steps of outsourcing decision-making procedure.

## 6. CONCLUSION

Supply chains are dynamic in their nature, and processes are managed with a smaller or larger degree of uncertainty and risks, which affects the variability and uncertainty of a need for transport services.

Transport outsourcing does not reduce the risks associated with the negative impact of dynamic characteristics of supply chains on transport performance (here: external outsourcing risks), but it can transfer them from transport service customer to the carrier. Moreover, one of the major reasons for popularity of transport outsourcing may be pushing a part of supply chain risks from transport service customer to transport service provider. Actually, a need to minimize risk in such way is often in behind

the term “flexibility”, one of the most cited reasons for outsourcing. Virtually, outsourcing reduces risk and increases flexibility of the company expressed in the response time to unknown conditions. However, the introduction of new entities and relationships always brings new risks in the supply chain. It is proposed a conceptual model, that consider both types of risks and they are connected with transport outsourcing goals. The important implication of this research is that a decision on transport outsourcing, from the risk perspective, should be made by taking into account both types of risks. The proposed model contributes to the normative research on outsourcing decision-making procedure, because it connects the supply chain management strategy with the transport outsourcing goals from the supply chain and outsourcing risk perspective.

#### ACKNOWLEDGMENT

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## SETTING UP CENTRALISED DISTRIBUTION

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**Abstract:** *Supplying of customers represents fundamental driving force for every region and has strategic importance for all participants along supply chain. Due to non optimised routes, poor planning and coordination among all parties involved in supply chain increased transportation costs are very likely to occur. In order to avoid unnecessary expenses and deterioration of overall logistics service level many different solutions can be applied. This paper describes in short advantages and disadvantages of centralised distribution strategy and its impact on logistics service level. Also practical examples for getting through the process of setting up this strategy in both supplier and retailers organization will be explained.*

**Keywords:** *centralised distribution, logistics costs, logistics collaboration.*

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### 1. TYPES OF DISTRIBUTION

The most common classification of distribution strategies is into:

- Decentralised
- Centralised
- Combined

Centralised strategy represents organising delivery of product from suppliers to a central location, usually in full load quantities, rather than to each store. After receiving, products can be stored again, processed (VAL) or picked and consolidated from a number of suppliers and delivered to the stores, usually in a single full load.

Decentralised distribution is a mean of organising delivery to each store individually. [1]

Combined distribution is rare but can be determined as partially centralised and decentralised. This special type can evolve from retailer's need to deliver specific group of products from central warehouse, or to receive products in stores based on their size (small ones) directly from supplier. Sometimes it just represents compromise between supplier and retailer.

#### 1.1 Centralised distribution

Centralised distribution is dominant strategy in majority of developed supply chains. The process involves entire warehousing system as an additional participant in the supply chain which adds more

complexity (Figure 2). Nevertheless Figure 1 shows that the supply chain in centralised distribution is much more simple and therefore more efficient than decentralised distribution (for both supplier and stores it brings a significant reduction of workload and costs). The reduction of costs is caused by the reduction of cost drivers (number of orders, executors etc.) as well as by the fact that the larger quantity of goods transported to and from the warehouse induces the reduction of transportation costs. That is optimal for large-volume and fast-turnover products.

Due to summing of picking demands in suppliers/distributor warehouse, other logistics cost are also decreased. First of all manipulation and labor cost because redundant process of picking lines, quality and quantity control, consolidation and loading is eliminated. Administrative costs related to order processing are dramatically cut and reverse logistics can be simplified by gathering returns from retailer's central warehouse. [2]

If centralised strategy is implemented, retailer will have increased logistics cost (breaking loads for stores and transport to each store) and overall stock level (including every store and central warehouse) will be larger but better monitored. If stock is not efficiently monitored, „out of stock“ situations can be everyday challenge that will lead to investment in increasing stock level.

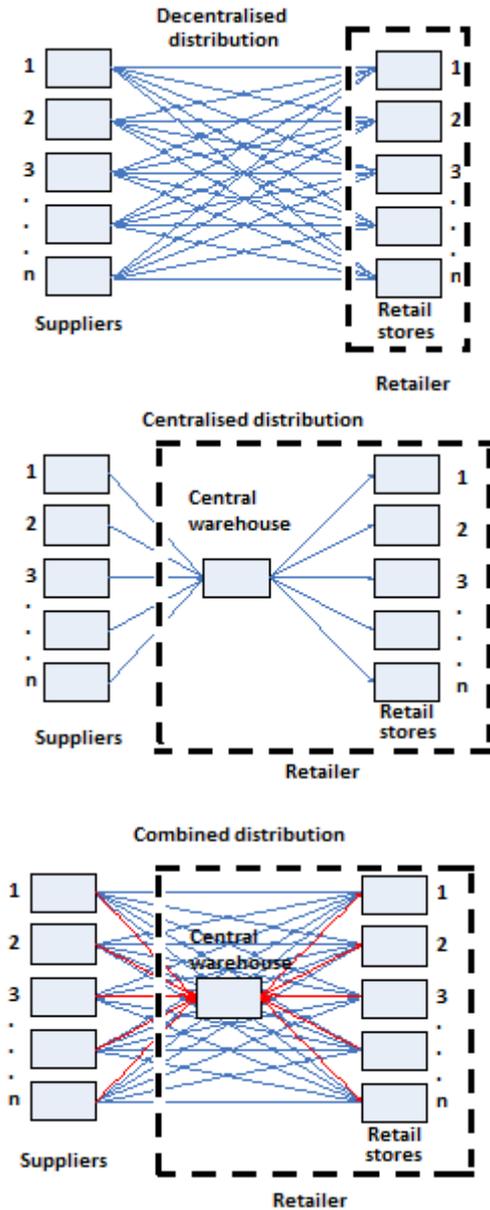


Figure 1. Schematic representations (decentralised, centralised and combined distribution)

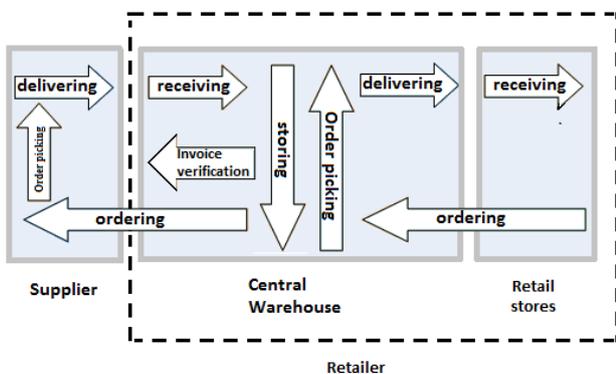


Figure 2. Schematic representations of centralised distribution processes

To sum up, the advantages of the centralised distribution are:

- Increased utilisation of truck loads, which leads to
- Decreased transportation cost per transported unit
- Decreased total number of vehicles used
- Decreased kilometres travelled in total
- Decreased number of documents and claims
- Increased reliability
- Decreased time for receiving products in total (one reception vs. multiple receptions)
- Decreased total route time
- Increased vehicle turnover
- Significantly decreased transportation costs
- Increased product availability and at the same time decreased stock in retail stores (short replacement time)
- Decreased stock level in retail stores (Total stock is increased) – shown in Figure 3
- Decreased „out of stock“ level in retail stores – shown in Figure 4.
- Decreased handling work in the store (net capacity in the stores)
- Decreased costs (reduction of buying price – logistics discount – vs. in-house logistics costs)
- Decreased complexity of the logistics in general
- Decreased administrative workload (invoices, packing lists, credit notes)

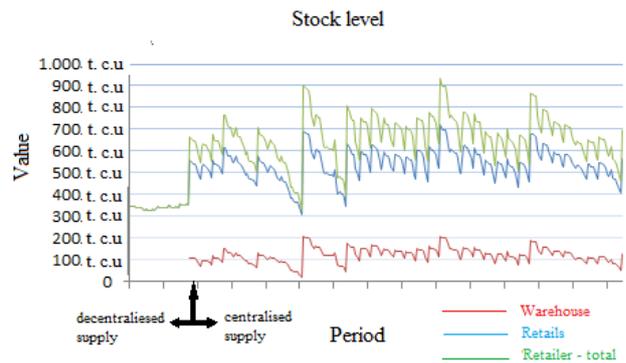


Figure 3. Chart of the stock level before and after centralisation in the company dm-drogeriemarkt

From transporter's point of view (if there is subcontracting party involved) centralised distribution brings less income but it can be compensated through greater vehicle turnover (more routes with the same vehicle).

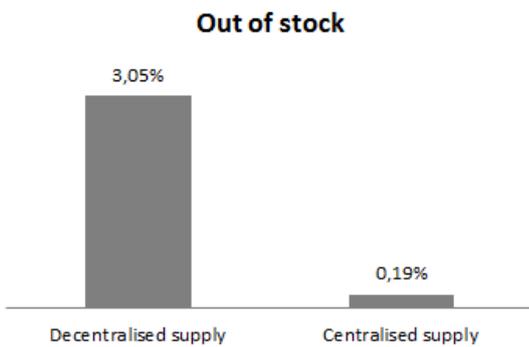


Figure 4. Chart of the OOS-level before and after centralisation in the company dm-drogeriemarkt

### 1.2 Decentralised distribution

The characteristic of this alternative is the simplicity of the process. The few process steps are easy to perform. However, sales increase in retailer's chain and diversification of goods induce the rapid cost increase (ordering/receiving by retailers and transportation costs by suppliers). For the suppliers it is difficult to process „many small“ orders, as well. This alternative is optimal for low-volume and slow-turnover products.

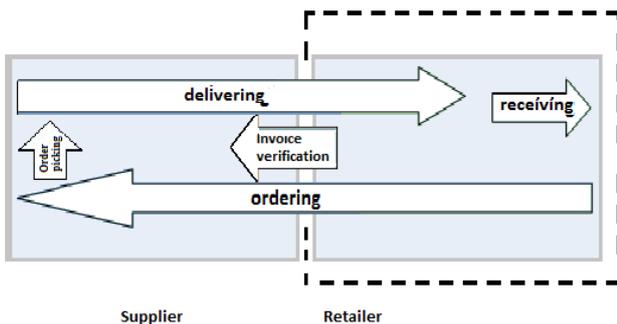


Figure 5. Schematic representations of decentralised distribution processes

Decentralised distribution can be seen in retail supply-chains where retailers have neither enough warehouse space nor the capacity for adequate stock control in their objects. In these cases decentralised distribution is only feasible. On the other hand, it is not uncommon for distributors to insist on decentralisation because of their insecurity about the benefits of centralisation and because they fear losing their presence/on site control in the distribution channels, while their sales force, and turnover diminishes. This misconception is huge obstacle for setting up centralisation and is dealt through detail calculation and cost benefit analysis.

Every benefit cited earlier considering centralised distribution can be seen as drawback for decentralisation. Transportation costs are much higher, as well as number of used vehicles, kilometres travelled, total receiving time. Transport

utilisation is diminished, uncertainty of delivery is greater, as well as manipulation costs, labor and reverse logistics. Conditional advantage can be shorter lead time and less stockouts (not likely in real terms). Decentralisation costs more but it can be managed to acceptable level through collective transport.

## 2. DECIDING ON DISTRIBUTION STRATEGY

For evaluation of each mentioned strategy it is necessary to determine all relevant factors such as:

- Users demands
- Locations of users
- Demanded service level
- Overall cost and distribution cost [3]

Detailed analysis needs to be taken from the perspective of every participant in the supply chain – supplier, retailer and logistics provider if there is one [4]. The retailer usually demands to split the increased costs with the supplier, who, on the other hand, debates with the logistics provider to review the price of his service.

In this complex relation a high-class collaboration is needed. Collaboration can be defined as “the means by which companies within the supply chain work together toward mutual objectives through the sharing of ideas, information, knowledge, risks, and rewards”. Technology and relationship building are critical components, and companies with effective collaboration skills are likely to have a competitive edge. [5]

The result of this collaboration will enable the transfer of decreased costs to the end price of the product (trade discount). In that way the retailer can compensate his increased costs. The trade discount is a subject of a detailed analysis, which is primarily comparison the costs of the current supply strategy (decentralised) with the possible variants (centralised, combined). The trade discount is usually equal to savings made from the decreased logistics costs of the supplier (transportation costs, order processing, picking, reverse logistics etc.). Arguments for the choice of strategy lie in two criteria:

- Costs - The cost analysis should show the difference in logistics costs between the compared strategies, considering the costs in the retail sector based on the net performance trend in the process of ordering, receiving etc.

- Service quality - The primary effect is the increase in the service level in the stores as well as the increase in the presence of products for the end-consumer.

Every process of every strategy needs to be identified and analysed. Related processes considered for the analysis can be shown as follows (Table 1):

**Table 1. Defining the process for supply strategy [6]**

process/strategies	Decentr.	Combin.	Central.
Ordering (Retail store)	x	x	x
Order processing (Central warehouse)			x
Ordering from the supplier (Central warehouse)			x
Order processing (Supplier)	x	x	x
Order picking (Supplier)	x	x	x
Transport to the Central warehouse		x	x
Transport to the retail stores	x	x	x
Receiving (Central warehouse)			x
Storing (Central warehouse)			x
Order picking (Central warehouse)		x	x
Receiving (Retail store)	x	x	x
Invoice verification	x	x	x

Legend:

Retailer costs	x
Supplier costs	x

After the cost identification, a cost analysis has to be performed, which involves following:

- Definition and description of cost factors and cost drivers
- Calculation of cost rates
- Calculation of costs for each strategy
- Calculation of the minimal discount for each strategy

The cost factor (CF) represents all costs with the significant influence on total costs in a certain process phase - employee salaries, transportation costs (fuel, maintenance, amortizations, labor, insurance, registration), warehouse costs (rent, manipulation, insurance, labor, amortization of warehouse and equipment, auxiliary goods, maintenance of forklift and other equipment), administration costs, etc.

Cost drivers (CD) are factors which influence total costs quantitatively. Example: Transportation costs grow with the number of transported pallets. In this case, the number of pallets is the cost driver. In the receiving process the costs depend mostly on the number of received items (orderliner). In this case, the number of received items represents the cost driver.

The cost rate (CR) is the number expressed as monetary value and represents the costs per cost driver and calculated cost rate for each process (presented in Table 1). In the receiving example the cost drive would be the price per received item.

$$CR = \frac{CF}{CD} \quad (1)$$

Financial analysis include actual costs through certain period of time (month, quartal, year):

Core and dynamic data:

- Turnover (financial value, weight, volume, pieces, products/positions, cartons, pallets etc.)
- Number of retails orders
- Number of actual routes
- Number of delivered shops (points)
- Parameters (assumptions):
- planned number of retail stores
- growth of market share (business plan)
- retailer's desired range of storage
- retailer's order and delivery plan
- number of working days etc.

**Table 2. Calculation of supply strategy analysed in dm-drogeriemarkt - part I**

Core, dynamic data and assumptions:				
Period:	1.2.2012-31.1.2013			
Financial value of turnover (c.u.):				100.000
Number of active products:				69
Planned number of retail stores:				69
Retailer's desired range of storage:	stores	15 days		
	warehouse	30 days		
Strategy: decentralised distribution				
Processes	cost rate (c.u.)	cost driver	core and dynamic data (c.u.)	total costs (c.u.)
Ordering (Retail store)	0,02	orders	3.588	56
	0,01	positions	49.514	583
Order processing (Supplier)	0,09	positions	49.514	4.352
Order picking (Supplier)	0,02	positions	49.514	1.168
Transport to the Central warehouse	28,00	pallets	14	397
Receiving (Retail store)	0,09	deliver	3.588	340
	0,02	positions	49.514	1.167
Invoice verification	0,22	invoice	3.588	788
<b>Total costs:</b>				<b>8.852</b>

The minimal discount expected by the retailer is the percentage of increased costs for the given supply strategy in sales generated in the given period. It represents the base for supplier's decision about which strategy will be implemented. Supplier's first simulation of new cost for centralised distribution and warehousing is taking in

consideration the same amount of volume transported with bigger vehicles less frequently, with less number of orders, less picked lines, goods control and loads. Then two calculations (actual cost vs. simulated cost) are compared. If centralised distribution brings the reduction of costs for the supplier, it is clear that centralised distribution will be set up. However, in practice this supply strategy is sometimes chosen for other reasons than cost reduction – because the participants in the supply chain see their benefit in better availability of goods in retail stores, OOS reduction, process simplification etc.

### 3. STEPS FOR SETTING UP CENTRALISATION

The first step is always the difficult one. Initiatives for centralisation are in most cases initiated from retailer's side. The first step is to get support and positive feedback from every party involved. This is where supply chain specialist's role is crucial. Initial meetings are taking place where all benefits for the company from centralisation are being explained. In start this idea usually will not be accepted with the distributors side but then calculation is needed to be done. After calculation of savings is finished sales representative is getting used to the fact of centralisation. Negotiations are being held with retailer.

A lot of details are discussed. Collaboration with IT department, sales and logistics from both sides is necessary. After several iterations a formal agreement will be signed in which:

- Ordering/delivery cycle is defined
- Ordering channel is defined (EDI, HH, fax, phone...)
- Order information is defined
- Minimum order quantity is defined
- Master data is being inspected and shared with retailer
- Updating of master data protocol is defined
- Logistics requirements for consolidation of full loads are being instructed
- Details for receiving goods in central location are defined
- Returns policy is defined
- Logistics service level is defined (KPI)
- Conditions for changing agreement are defined
- Commercial terms are defined

**Table 3. Calculation of supply strategy analysed in dm-drogeriemarkt - part II**

Strategy: centralised distribution				
Processes	cost rate (c.u.)	cost driver	core and dynamic data (c.u.)	total costs (c.u.)
Ordering (Retail store)	0,02	orders	3.588	56
	0,01	positions	49.514	583
Order processing (Central warehouse)	0,30	orders	3.588	1.076
Ordering from the supplier (Central warehouse)	0,18	positions	1.196	221
Order processing (Supplier)	0,09	positions	1.196	107
Order picking (Supplier)	0,02	positions	1.196	29
Transport to the Central warehouse	6,00	pallets	14	85
Receiving (Central warehouse)	0,23	positions	1.196	279
Order picking (Central warehouse)	0,03	positions	49.514	1.485
Storing (Central warehouse)	19,64	pallets	14	278
Transport to the retail stores	30,00	pallets	14	425
Receiving (Retail store)	0,09	deliver	3.588	340
	0,02	positions	49.514	1.167
Invoice verification	0,22	invoice	52	12
<b>Total costs:</b>				<b>6.145</b>
Compare costs of decentralised supply				
Participants	percentage of turnover	percentage of total costs	currency unit (c. u.)	
Supplier	8,58%	66,84%	5.917	
Retailer	4,25%	33,16%	2.935	
Total	12,83%	100,00%	8.852	
Compare costs of centralised supply				
Participant	Percentage of turnover	Percentage of total costs	currency unit (c. u.)	
Supplier	0,32%	5,16%	221	
Retailer	8,58%	94,84%	5.924	
Total	8,91%	100,00%	6.145	
Summary				
Increased costs for retailer (c.u.)			2.988	
Increased costs for retailer (%)			2,99	
Decreased costs for supplier (c.u.)			5.696	
Decreased costs for supplier (%)			5,70	
Decreased in total supply (c.u.)			2.707	
Decreased in total supply (%)			2,71	

There are many participants in the supply chain who need to adopt the new way of doing things so all details must be clarified and set up before getting started. If some of the above-named steps are not clear, the end result will not be the best, and even

more costs will be generated in order to adjust logistics operations on both sides.

#### 4. CONCLUSION

Centralised distribution is a proven method for increasing product availability in retail stores and making considerable saving through reduced number of deliveries of full loads made up from a multiple supplier's products. Before implementation every party involved needs to be careful and prepare their organizations for dramatic change. If the setup is done correctly, overall service level will be improved.

Further impact of centralisation will consider social and environmental perspectives. Due to minimisation of workers, regions with high number of warehousing facilities will be affected the most. Not to forget that centralised distribution also has

benefits to the environment via reducing traffic congestion and noise reduction in urban areas.

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# THE SIGNIFICANCE OF EFFICIENT LOGISTICS AND SUPPLY CHAIN MANAGEMENT PRACTICES FOR MACEDONIAN SMALL AND MEDIUM ENTERPRISES

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***Abstract:** Globalization of economy as a process enables a creation of a single market and logistics and supply chain management are important tools in this process. A market with efficient logistical and supply chain management capacities has a comparative advantage over other economies. Trade logistics and supply chain management are critical for developing countries to improve their competitiveness, reap the benefits of globalization, and fight poverty more effectively in an increasingly integrated world. Success in integrating global supply chains starts with the ability of companies to move goods across borders rapidly, reliably and cheaply. In order to connect the Macedonian economy to the world trends and processes and connect the Macedonian market to the European and the world market, the highest priority should be given to the development of logistics and supply chain management in Macedonia. This paper elaborates the current level of logistics and supply chain management development in Macedonian small and medium enterprises.*

***Keywords:** logistics, supply chain management (SCM), Macedonia, small and medium enterprises (SMEs).*

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## 1. LOGISTICS AND SUPPLY CHAIN MANAGEMENT IN MACEDONIA IN GENERAL

The current level of development of logistics and SCM in Macedonia cannot be evaluated as satisfactory, but Macedonia has a strategic territorial position that offers opportunities to develop effective business logistics and SCM. The main advantages of Macedonia for developing a logistics concept are the favourable geographical position and the level of development of traffic and other infrastructure. A positive trend in the development of logistics and SCM in Macedonia is the entry of the famous logistics companies such as: Logwin, Kuehne + Nagel, Gebruder Weiss, DHL, DB Schenker, Mediterranean Shipping Company (MSC), etc.

The following limiting factors facing the development of logistics and SCM in Macedonia can be identified:

- Macedonia is landlocked country;
- Insufficient foreign trade;

- Existence of a small number of companies offering integrated transportation, logistics and forwarding services. These are only the foreign companies mentioned earlier, while most of domestic companies operate only customs brokerage;
- Bureaucratic and administrative obstacles;
- Lack of support from all previous governments.

Despite the limitations specified, the geographic position of the country enables the function of a bridge across the center of the Balkan Peninsula and it makes it a special place to implement long-term logistics concept within the region. Therefore efforts are necessary to evaluate these favourable factors, and will connect with the modern logistics structures.

## 2. THE SMALL AND MEDIUM ENTERPRISES IN MACEDONIA

According to the data of the State Statistical Office the number of active business entities in the Republic of Macedonia in 2012 was 74424.

The sectors with the highest share in the structure of business entities were: Wholesale and retail trade; repair of motor vehicles and motorcycles with 27 307 entities or 36.7% and Manufacturing with 8 251 entities or 11.1%, whereas the least represented were the sectors Electricity, gas, steam and air conditioning supply with 134 entities or 0.2% and Mining and quarrying with 182 entities or 0.2%.

The data on the structure of active business entities according to the number of persons employed show that the highest share of 82.0% belongs to business entities with 1-9 persons employed, followed by business entities with no persons employed (or the entities did not provide information about persons employed) with 9.6%, and entities with 10-19 persons employed with 3.9%, the share of entities with 20-49 persons employed was 2.4%, those with 50-249 persons employed participated with 1.7%, while entities with 250 or more persons employed had a share of only 0.3%. [6, p. 1]

Nearly 99% of the companies in Macedonia are registered as small enterprises, employing nearly 55% of the employees in the private sector. According to the main activity registered, the majority of businesses are in the wholesale and retail trade sector (47%), manufacturing sector (13.1%), and the transportation, storage, and communications sectors (approximately 10%). The largest employer is the manufacturing sector, with 35.6% of the total number of employees in the private sector.

The Macedonian Government puts a high priority on the development of the SME sector, focusing on measures and activities to support the development and competitiveness of SMEs, and to improve the business environment in general.

From the aspect of its size and flexibility the SMEs represent the most dynamic but in the same time and the most vulnerable segment in the global economic structure of the country. That's why, the policy makers responsible for SME development, necessarily need a reliable mechanism for systematic follow up and assessment of the condition of the sector. It will further on, help them to select and carry out adequate measures providing the desired level of SMEs development. [1]

Chapman et al believe that SMEs can take advantage of the supply chain management strategy for various reasons: [3, p. 31]

- SMEs are critical links in many supply chains.
- SMEs are very flexible. Many SMEs are still young and developing and it is therefore easier for them to re-engineer existing

business processes and adopt a supply chain management approach than for large organisations with a long-standing organisational structure and culture. The integrated approach is inherently part and parcel of SMEs.

- SMEs follow an integrated approach by nature. Various business functions are usually performed by one or a few persons working together.
- Computer software programmes are more SME friendly. IBM, for example, started the service Smart Start, which allows SMEs to use IBM's expertise with information systems along with their own business expertise to find and implement ERP system solutions that work for their business.
- SMEs can also benefit from global competition. Supply chain management provides a method of addressing the competitive challenges facing business today.

Small businesses are therefore already vital links in the supply chains in which they participate. By virtue of their size, flexibility and expertise they possess advantages that they can use to benefit their supply chain and strengthen their own businesses.

Technology is increasingly affordable and available to help SMEs take advantage of supply chain strategies. Because of the competitive pressures facing small businesses it is critical for them to use supply chain perspectives and associated strategies to create synergies with supply chain partners in order to succeed in the global competitive environment [3, p. 34]. Despite the optimism of Chapman et al there is reason to doubt the general implementation of the supply chain management approach and willingness and ability to implement the approach by small businesses. [2, p. 5]

### **3. THE SIGNIFICANCE OF EFFICIENT LOGISTICS AND SUPPLY CHAIN MANAGEMENT PRACTICES FOR IMPROVING MACEDONIAN SMES' COMPETITIVENESS**

In recent years, effective logistics and supply chain management have been recognized as key opportunities for improving the profitability and the competitive performance of the companies. Also in the last few years, a significant progress in the field of small and medium enterprise development in Macedonia has been seen.

The reason for the existence of the supply chains is that there are very few companies that can produce end products for end-customers from raw materials on their own, without the assistance of other organizations. The company that produces the raw material is often not the same company that sells the end products to the end-customer. In order to provide end products to the end-customers, a network of actors is involved in activities (as purchasing, transforming and distribution) to produce products and/or services. All of these actors add value to the end product. The series of companies that interact to produce end products, and to contribute to the value of end products, is actually the supply chain. [4]

SC performance will be a key indicator of overall corporate success in the upcoming period and core advantage when entering foreign markets and compete with low cost countries.

Consequently, the competition is no longer between companies but between supply chains. The goals of the entire supply chain become the common objective of each company. Cost and service improvements that were not achievable by individual companies will now be attained by cooperating companies. [5, p. 5]

SMEs with efficient logistics and SCM will be able to maximize their profitability and improve their competitiveness.

The large companies in Macedonia, although they exist in small number, have developed logistics and SCM system. This is especially the case with the companies that were privatized during the transition period and where a foreign investor is a dominant shareholder. Usually in these companies the main advantage is that they use the experience, the know-how and the benefits from the already well established logistics and SCM system in the parent company, located in some foreign country.

The successes achieved by organizations that implement the strategic supply chain management approach will certainly have a positive impact on the popularity of the approach and a trend towards implementing the supply chain management approach by increasingly more organizations is to be expected. This trend will undoubtedly influence small and medium-sized businesses (SMEs). Many SMEs are already supplying materials, products and services to large organizations. Hence, the adoption of the strategic supply chain management approach by large organizations in supply chains will have a definite impact on them (SMEs). [2, p. 2]

It is obvious that the position of the SMEs regarding the SCM is not as favorable as for the large companies. If we have in mind the fact the

SMEs dominate in the Macedonian economy, we can say that the development of the Macedonian economy is based on the development of the Macedonian SMEs. That is why this paper is focused on research about the level of development of logistics and SCM in the Macedonian SMEs.

#### 4. RESEARCH FINDINGS

The research was made through a web based questionnaire, which was sent to 68 managers of small and medium enterprises from various industries in the Republic of Macedonia. The sample was chosen on a random basis. The questionnaire was answered by 55 managers and only those answers are included in the analysis.

Out of the 55 interviewed managers, 28% are from SMEs from the manufacturing sector, 44% from the service sector, and 28% are offering both products and services.

It is disappointing that only 37% of the SMEs have a separate logistics department and 63% do not have. From the companies that do not have a separate logistics department, 77% plan to establish one in near future, 13% do not know if they will and 10% do not plan at all. Of course this is an encouraging fact. 54% of the interviewed managers think that there is a need for organizational change for SCM adoption in the company, 33% think that there is no need for organizational change and 13% do not have opinion about this issue.

Regarding the current public policy towards SCM, 34% of the interviewed managers are not satisfied, 27% are satisfied and 19% are very satisfied.

On the question How do you manage your supply chain?, we got the following answers: 34% have close partnership with suppliers, 39% have close partnership with customers, 25% use outsourcing, 23% are holding safety stock, 21% use subcontracting, 14% use Supply Chain Benchmarking, and 12% use Vertical integration. These are the most popular methods among the Macedonian SMEs, while we got negligible percentage (i.e. almost no one) for using other sophisticated methods, such as: Electronic Data Interchange (EDI), e-procurement, Just-in-Time (JIT) supply, Third Party Logistics Providers (3PL), Fourth-party logistics provider (4PL) and similar.

13% of the interviewed managers think that their company is not successful at all in managing its supply chain in general, 34% think that they are just not successful, 28% think they are somewhat successful, 17% think they are successful and only 8% think that they are very successful. These figures

are disappointing, but the managers are aware of the fact that there is a need of implementing different systems in the companies for supporting the Supply Chain Management. More of the half of the interviewed managers believe that the Supply Chain Management in the company will be supported strategically by the implementation of the following systems: Material Requirements Planning (MRP), Manufacturing Resources Planning (MRPII), Enterprise Resource Planning (ERP), Warehouse Management System (WMS), Customer Relationships Management (CRM), Supplier Relationships Management (SRM), E-commerce, Radio Frequency Identification (RFID), Bar coding and Electronic Data Interchange (EDI). Nearly three-fourths of the interviewed managers strongly believe that the companies will achieve great benefits with the implementation of those systems, such as: better quality and quantity of information, reduced lead-time in production, reduced inventory level, better operational efficiency, increased coordination with suppliers and customers and flexibility. But, they are of course aware that the implementation of these systems is very expensive and a long-run project, probably as SMEs they will not be able to implement most of these sophisticated systems, so as a solution for overcoming the unfavourable level of logistics and SCM development in the SMEs, they are planning to implement the following future measures for supporting the company effort in logistics and SCM by raising the awareness of the importance of these topics: More funding and financial support (73%), More formal education (65%), Easier access to vocational training (62%), Better infrastructure (61%), Increased regional cooperation between institutions (59%), Closer cooperation between companies and governments (57%) and Improved information provision (54%).

## 5. CONCLUSION

Success in integrating global supply chains starts with the ability of companies to move goods across borders rapidly, reliably and cheaply. In order to connect the Macedonian economy to the world

trends and processes and connect the Macedonian market to the European and the world market, the highest priority should be given to the development of logistics and supply chain management in Macedonia. It is obvious that for the large companies it is easier to reap up the benefits of the well established logistics and SCM division. The position of the Macedonian SMEs regarding the SCM is not as favorable as for the large companies. If we have in mind the fact the SMEs dominate in the Macedonian economy, we can say that the development of the Macedonian economy is based on the development of the Macedonian SMEs. That is why this paper is focused on research about the level of development of logistics and SCM in the Macedonian SMEs. Macedonian SMEs must fully understand the supply chain management approach and their role. Large organizations, however must realize that, despite their size, SME suppliers are important partners who can contribute substantially to savings in the supply chain. Only in this way they can increase their profitability and competitiveness and become integral parts of the global supply chains.

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## THE STEADY STATE PRICE ANALYSIS OF TWO STAGE SUPPLY CHAIN

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**Abstract:** *This paper is given over to steady state price analysis of two stage supply chain with homogeneous products. It is assumed with one producer at the beginning of supply chain and one end customer characterized with aggregated demand at the end of supply chain. As intermediate nodes of supply chain, two vendors supplying product from producer to consumer are considered. The aim of suppliers, unlike in classical approaches that maximizing profit, is to maintain market share in the segment sales of the product. The analysis is based on equilibrium between linear supply and demand functions at both sides of the supply chain. The result is the evaluation of the equilibrium strategy of subjects at both sides of the supply chain and analyses how different actors have to adapt their pricing strategy.*

**Keywords:** *supply chain, steady state price, microeconomic analysis.*

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### 1. INTRODUCTION

In recent years supply chain management has focused its attention on managing decentralized entities operational decisions, that have an impact on supply chain profit and thus to all other actors in the supply chain.

Classical analysis of supply chain effectiveness are focused on examining the situation where the supply chain gain diversifies among its entities and at least one has a relevant impact on the demand for goods (Fiala, 2002). More recent trends are focused on the utilization of natural tool in maximizing entities own utility market function with the regard to the behavior of other market actors - the game theory [1], [4]. Microeconomic analysis based on steady states of supply or demand functions can be effectively used too [2].

Nowadays, attention on creation of supply network structures has increased and natural requirement is its optimization. Network structures are formed by separate entities of supply chain, among which mutual cooperative ties exist. Its optimization is result of an effort to maximize the efficiency of the entire supply chain, thus optimization of supply chain management from producers via distributors to the final customers. Maximum efficiency can be achieved only in

conditions of mutual cooperation among various actors in the supply chain and the optimization of material and information flows, as well as the willingness of subjects to participate in the global supply chain optimization (so-called cooperative decision-making) [3], [5], [6].

With increasing number of supply chain entities different network structures can be achieved. In supply chain structures two types of interactions are distinguished one-to-one and many-to-one. According to interaction type serial, parallel and combined supply chain can be considered. Figure 1 illustrates structures of serial, parallel and combined supply chain in order from the top to the bottom.

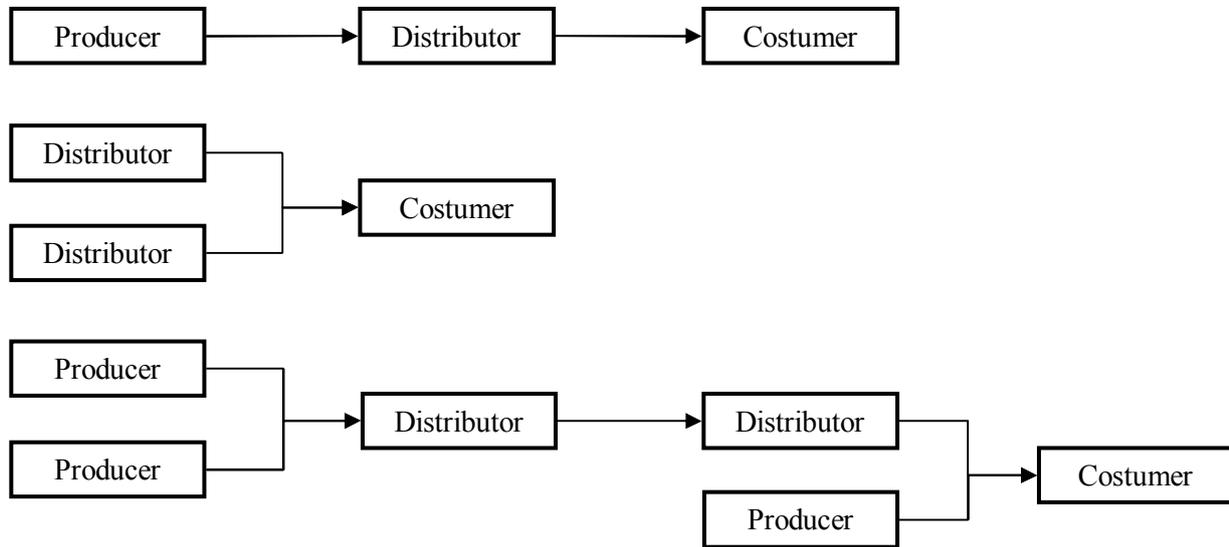
According to number of interactions at various levels of supply chain one or multiple stage supply chain is distinguished.

### 2. TWO STAGE SUPPLY CHAIN

Let suppose that in the supply chain, there is an intermediary, for example in a real situation the manufacturer does not sell its product directly to final consumers, but sell it through wholesale warehouses or chain stores, etc. In this case, we simply assume that the beginning of the supply chain is represented by the manufacturer of the product, end of the chain is represented by end customer characterized by aggregated demand for a

product that passes between two intermediaries in the supply chain, which consists of two entities (intermediate warehouses). Let denote producer by

the letter  $P$ , end customer by the letter  $C$  and intermediaries by letters  $S_1$  and  $S_2$ .



**Figure 1. Serial, parallel and combined supply chain**

Beside the classical objective of individual actors in the supply chain that is the profit maximization (from customer point of view cost minimization of purchased goods), other objectives can be set. In further analysis we will consider objective to obtain or maintain market share in given product segment sales under consideration, product passes through multiple stage supply chain. From above stated assumptions, we will analyse supply function on the first stage of supply chain (between producer and intermediaries) and demand functions at second stage of supply chain (between intermediaries and end customers), in order to generate price equilibrium at various stages of the supply chain. By evaluation of the equilibrium strategy, it can be analysed which entity of supply chain and how it should adapt its strategy. For simplicity, we will

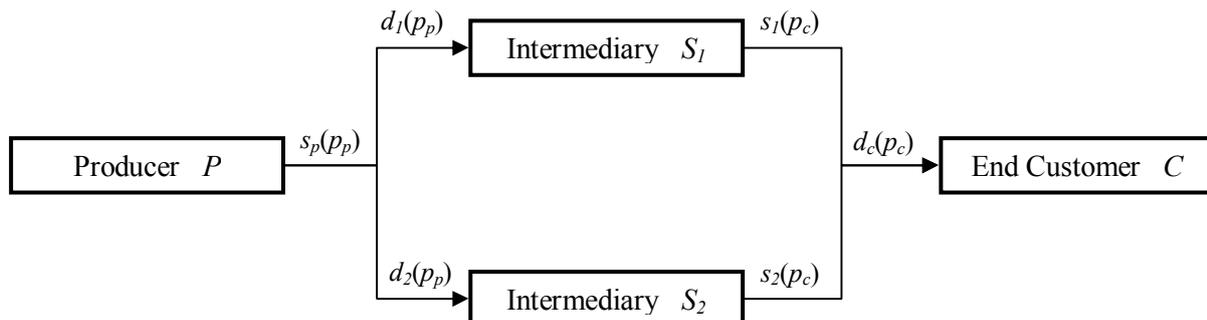
consider the linear form of supply and demand functions for each of supply chain actor.

Considered case can be represented by graphic model depicted on the Figure 2.

Let assume that, producer  $P$  supply quantity depends on the selling price and it can be expressed as a linear supply function:

$$s_p(p_p) = c_p + d_p p_p$$

where  $c_p$  denotes the smallest value of producer  $P$  supply,  $d_p$  denotes marginal increase of producer  $P$  supply  $p_p$  denotes the unit price of the product in the first stage of the supply chain.



**Figure 2. Two stage supply chain**

Let assume that, on second stage of supply chain two intermediaries  $S_1$  and  $S_2$  operate (duopoly market structure), whose linear demand functions on considered product depend on the price from the first stage and it can be stated as:

- For the first intermediary  $S_1$ :

$$d_1(p_p) = a_1 - b_1 p_p$$

where

$a_1$  denotes saturation level of demand of the first intermediary  $S_1$ ,

$b_1$  denotes marginal decrease of first intermediary  $S_1$  demand,

$p_p$  denotes the unit price of the product in the first stage of the supply chain.

- For the second intermediary  $S_2$ :

$$d_2(p_p) = a_2 - b_2 p_p$$

where

$a_2$  denotes saturation level of demand of the second intermediary  $S_2$ ,

$b_2$  denotes marginal decrease of second intermediary  $S_2$  demand,

$p_p$  denotes the unit price of the product in the first stage of the supply chain.

On the second stage of supply chain it can be assumed, that considered intermediaries  $S_1$  and  $S_2$ , implement supplier relationship with the last level of supply chain and supply for end consumer is represented by linear supply functions:

- For the first intermediary  $S_1$ :

$$s_1(p_c) = c_1 + d_1 p_c$$

where

$c_1$  denotes the smallest value of first intermediary  $S_1$  supply,

$d_1$  denotes marginal increase of first intermediary  $S_1$  supply,

$p_c$  denotes the unit price of the product in the second stage of the supply chain.

- For the second intermediary  $S_2$ :

$$s_2(p_c) = c_2 + d_2 p_c$$

where

$c_2$  denotes the smallest value of second intermediary  $S_2$  supply,

$d_2$  denotes marginal increase of second intermediary  $S_2$  supply,

$p_c$  denotes the unit price of the product in the second stage of the supply chain.

On the second stage of supply production is delivered to the end customer characterized by aggregated demand which linear function can be stated as:

$$d_c(p_c) = a_c - b_c p_c$$

where

$a_c$  denotes saturation level of demand of end customer  $C$ ,

$b_c$  denotes marginal decrease of end customer demand  $C$ ,

$p_c$  denotes the unit price of the product in the second stage of the supply chain.

Based on above assumed assumptions price steady state can be found for each stage of supply chain:

- steady state price strategy among producer  $P$  and intermediaries  $S_1$  and  $S_2$  assuming the same purchasing price  $p_c$  for both intermediaries, can be calculated based on relations:

$$(a_1 - b_1 p_p) + (a_2 - b_2 p_p) = c_p + d_p p_p \quad (1)$$

$$\frac{a_1 + a_2 - c_p}{b_1 + b_2 + d_p} = p_p$$

Steady state price  $p_p$  for the first stage of supply chain is increasing with increase of demand saturation level of both entities ( $a_1$  and  $a_2$ ) and decrease of parameter for smallest supply value  $c_p$ , coefficient of supply growth  $d_p$  and marginal demand decrease of intermediaries ( $b_1$  and  $b_2$ ). In case of opposite values of stated coefficients, the steady state price for the first stage of supply chain is decreasing.

- Steady state price strategy among intermediaries  $S_1$  and  $S_2$  and end customers  $C$  assuming the same purchasing price  $p_c$  for both intermediaries, can be calculated based on the relationship:

$$(c_1 + d_1 p_c) + (c_2 + d_2 p_c) = a_c - b_c p_c \quad (2)$$

$$\frac{-c_1 - c_2 + a_c}{d_1 + d_2 + b_c} = p_c$$

Steady state price  $p_c$  for the second stage of supply chain is increasing with increase of

demand saturation level of end customer  $a_c$  and decrease of parameter for smallest supply value of both intermediaries ( $c_1$  and  $c_2$ ), both intermediaries marginal increase of supply ( $d_1$  and  $d_2$ ) a marginal decrease of end customer demand  $b_c$ . In case of opposite values of stated coefficients, the steady state price for the second stage of supply chain is decreasing.

### 3. CONCLUSION

Based on the considerations stated, price  $p_p$  and  $p_c$  can be analyzed, if  $p_p < p_c$  is true. Difference  $p_c - p_p$  represents supply chain intermediary margin. The situation, however, occurs when the same amount of trade conducted on the first and the second stage of the supply chain under consideration is realized. In case of smaller value of supply realized at the first stage of the supply chain, entities which represent an intermediary in the supply chain decide whether to increase the demand for goods from the producer, which can be achieved by increasing the price that is paid for the product. The same effect can be achieved by increasing the end customer price, resulting in a reduction of demand for the product.

In case of greater value of supply realized at the first stage of the supply chain entities which represent an intermediary in the supply chain, must deal with this situation in the opposite way.

Price strategy selection in the supply chain is determined by a number of indicators, because, as mentioned above, entities that act as intermediary bodies in the supply chain, in addition to profit maximization have objective to maintain market position. Accordingly it is appropriate to make a

further analysis, for example analysis based on game theory, which provides the appropriate tools to deal with this kind of problem, ie determine which method of settlement of steady state pricing strategy in the first and second stages to use.

### ACKNOWLEDGMENT

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**Part VII**

**TOOLS IN LOGISTICS  
TRAINING AND EDUCATION**

# BEERGAME REFERENCE SCENARIOS FOR BALANCED SCORECARD EVALUATION, HIGHLIGHTING CUSTOMER PERSPECTIVE

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**Abstract:** *The BeerGame software is continuously developed in the Szabó-Szoba R&D Laboratory based on the original game invented by J. Forrester. This simulation helps the students, researchers, managers to understand the so-called system dynamics of supply chains. The software is applied on tablets or smartphones what makes us possible to hold trainings anywhere, easily. It's also suitable to integrate the Balanced Scorecard measurement system. In that way we can see the graphs and results immediately after the games and to create KPIs, statistical examinations. The most important part of the trainings is the discussion of outcomes and the team learning because the application of modern production and distribution strategies requires flexible innovative thinking and special management skills from experts: to construct and manage effective, well-balanced manufacturing and logistics process. In our paper we are focusing on the customer perspective to identify individual and general rules on the field of partnership in supply chain management.*

**Keywords:** *bullwhip effect, beer game, Balanced Scorecard, performance measurement, partnership.*

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## 1. INTRODUCTION

The Beer Game logistics management game is widely used to demonstrate the inventory imbalance problems in supply chains – in the frame of the game participants impersonate a four stage supply chain, and make their own decision about actual orders in every round according previous demands and expectations. The factory is responsible for production, and the other three collaborators for distribution towards the customer. The aim of the players is rather simple: each of the four traders has to fulfil incoming orders by forwarding the required units of beers to the partners in the chain with minimal total cost (the charge of inventory holding is 1, in the case of backlog the related cost is 2 units of currency). Communication and collaboration are not allowed between supply chain stages. This game can be used in the formal education and on trainings as well to model real life situations and to highlight

the difference between practice and theory by the learning-by-doing method.

## 2. THE BULLWHIP-EFFECT

The competing supply chains are characterized by the ever growing extension. The need of mass-production is increasing in the industry while on the costumers' side the demand of unique goods is extending. These cross-purposes cause the elongation of supply chains and turn them into supply networks with more and more processing, forming, storage stations and resulting in huge transportation and forwarding needs. This system structure has a serious and inseparable drawback, the presence of the bullwhip-effect.

Because of the growing globalization of supply chains/networks we can observe in an increasing number the bullwhip-effect which is a really expensive phenomenon: at different stages of the distribution channels high inventory levels arise, although at the same time other stages suffer from

serious shortages. Therefore, the end users in many cases can't get the desired product, on the other hand, insufficient or excessive production and warehouse capacity establishment and its inappropriate coordination causes the inaccurate production, delivery and distribution plans. The consequences are growing total cost of supply chains, lower profit rate, and loss of competitiveness. The inappropriate usage of resources implies the increasing logistics costs and declining customer service and its adverse effects which worsen the performance of companies and supply chains.

The inventory levels at different points of supply chains varying separately from the real customer demand because of the bullwhip-effect. The usage of resources as production-, distribution-, and warehousing capacities is apparently not effective. The emerging shortage and unnecessary accumulation of inventories at different stages with the passage of time and the fulfillment of the backlogs of orders run through the whole supply chains. Therefore the systems/networks lose their balances and these swings maintain the presence of the bullwhip-effect for an indefinite time. Despite the fact that this phenomenon has been known for long time, its examination, accurate detection and modeling, is still subject of intense scientific interest. [6]

Based on many scientific researches the trigger of the bullwhip effect can be traced by the lead time of information and material. A supply chain's reaction on a change in end customer demand is delayed firstly because it takes time to pass on information about the change to suppliers and secondly because these suppliers need time to adjust their capacities and deliveries. The longer a supply chain is unable to react on a changed demand, the heavier it needs to react as soon as this is possible. The bullwhip effect increases with longer lead times.

In addition to the lead time of information and material, the bullwhip effect is caused by other reasons:

- Insufficient techniques for demand forecast
- Batch ordering
- Price fluctuation
- Exaggerated order quantity in case of shortage

Commonly, demand amplification is mostly caused by some internal mechanism or event; it is not due to something external to the system. Although the customer demand may be extremely volatile, it is self-induced worsening of any situation. As bullwhip is a time-varying

phenomenon, graphical representation of system behaviour is extremely helpful. The next figure shows specific demand amplification in a six month period. [5]

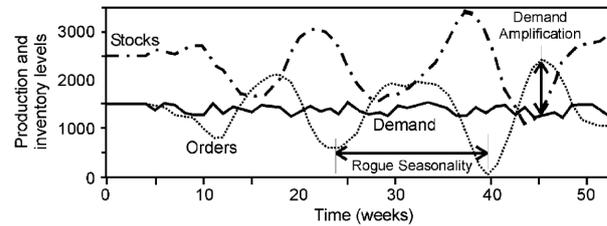


Figure 1. Demand amplification [2]

### 3. THE BALANCED SCORECARD SYSTEM AS PERFORMANCE MEASUREMENT APPROACH

We had to realize that the traditional efficiency measures by themselves – because they are considering mostly the financial parameters of production processes – are inadequate in providing a complete and useful overview of organizational performance (in our case it means the performance of the whole distribution channel as a system). For better understanding the relations not only on the operational, but also on tactical and strategic levels. The use of Balanced Scorecard measurement system is widely accepted: it is operating on the financial, marketing (customer-related), operational (internal-business processes) and strategic dimensions (learning and growth)(Figure 2).

#### Measures should Support Successful Implementation of the Strategic Plan

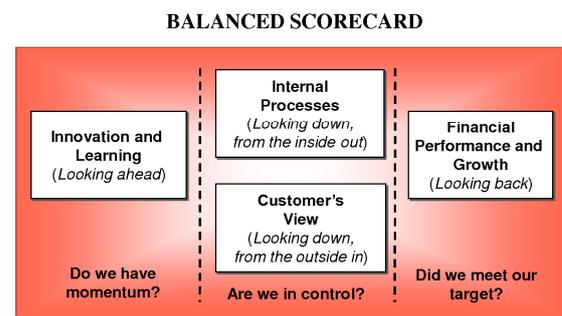


Figure 2. The perspectives of the Balanced Scorecard [4]

The **financial** perspective of course is the basic of the BSC measurement system, but this is the easiest to create exact numbers from which we can jump to a conclusion, and so it has lots of common attribute with the typical measurements systems. Also the truth is that the managers will always want to see clearly the data, trends, graphs, and use every possible instrument to learn where the company is

heading to, be aware of the risk assessment and cost-benefit data. This is why it's colligated with the other three perspectives, to see the whole picture. We can generate the most obviously measurable indicators in this area. We can exactly calculate the inventory holding cost and the penalty in case of shortage. We can also easily say the growth in the certain customer's orders, which refers our next perspective.

Examples:

- Lot of capital tied up in inventories
- Frequency and amounts of out-and in stores
- Storage costs depend on the size of the warehouse and the storage technology

In our trial gameplay the inventory levels moved quite simultaneous. Increase at one players stock caused the raise at the others. In this case quite natural that the retailer had the lowest and the factory owned the highest stock, so the parallel lowest and highest inventory holding costs.

The next factor is the **customer**, who should be satisfied. The management has to realise that the future of the company depends on the strong loyalty of the partners. Applying indicators on customer satisfaction may show hidden problems before our partner changes supplier. A possible way to separate our customers in different groups, and rate their different needs, then the customer service can get closer and closer to the needs based on this. We can think about more concrete tools here.

For example:

- How much late we can afford with the delivery of an order?
- How many times do we have to compensate, until the customer does not choose another supplier?
- How do we behave in the case of a missing product?
- Do we monitor the order amounts?
- What do we conclude from the orders gradient?
- Do we look for the underlying reasons in case of fluctuation in the orders?

The different inventory management strategies affect differently the relation with the customer. In our first try everybody had their own tactic for satisfying the demand. The high safety stock at the Factory was the best solution in this aspect but it conflicts with other goals.

To reach successes the **internal business processes** must be continuously improved and examined. It makes easier to the employees to

perform their tasks, minimise the possible mistakes and the managers can see the quality of the production or services. The problem with this perspective is that it requires very profound knowledge about every tiny detail of the internal business processes, so it can not be developed by an outsider consultant or expert. The internal processes of distribution channels contain lots of components. Forecasting, human and material resource planning, production and shipment scheduling can largely influence the efficiency of the company, and globally the performance of the chain. Usually there is not only one possible optimal way to fulfil the demand. Furthermore sometimes not possible to find the real optimum; just use any good solutions close to it.

Based on the experiences we can say it's a good way to treat the whole supply chain as one system. If we consider globally the factors maybe we can get closer to the best solution. A lot of question entails related to the internal processes:

- How much information do we share with the partners?
- Do we discuss our trading plans with our supplier?
- Are we able to manage a common inventory or trading plan with the others?
- How efficient is our capacity utilisation?
- Do we have idle resources in the shipments?
- What kind of forecasting method leads to the optimal resource allocation?
- What is the ideal safety stock level?

In the game we all paid huge attention on not sharing any information to see what will happen. The expectation was fulfilled, we finally created the bullwhip effect without any efforts (some managers may deliberately mislead the partners).

The last perspective is the **innovation and learning**. It both means the training of the associates and the self development of the company. With this nowadays technical improvement speed no one can afford to miss out these aspects. The employees have to be updated and also evaluated during their work. It's a good way if the company has a collective data base of specialised knowledge. The level of technical developments can be measured by adequate metrics (physical and quality indicators). This part should show us, how fast we can comply with new techniques, trends, and the fluctuation of the customer demands. Some adequate indicators can measure for example the technical or infrastructural development of the company. Yet there are some aspects of progression in the business

life which can be really affective but uneasy to evaluate.

- Peak management – treat the accumulated stock
- Don't panic – strategy in case of shortage
- IT systems – sequential improvement is necessary in every field of company governance including the product tracking, customer-supplier relationship management, inserting new methods in operational processes, development of corporate culture

With the BeerGame software we can create graphs to demonstrate the bullwhip-effect and its consequences regarding to the four BSC perspectives.

#### 4. CUSTOMER / PARTNERSHIP

In this case customers are mostly the trading partners, who order from our inventory. We can see their satisfaction, when we consider for example the “lifespan” of the relationship. If we have old partners with a long-term relation and common history, we should be doing something well. To have a concrete frame for our evaluations we use the following equations in the table below:

**Table 1. Equations used for Customer perspective [6]**

<i>Maximum Backlog of orders</i>	$BLO_{max} = X_{imax}$
<i>Average shortage</i>	$AS = \frac{\sum BLO}{n}$
<i>Maximum delay</i>	$\underline{x}_j, x_{i+1}, \dots, \underline{x}_j = BLO > 0 = (j - i + 1)_{max}$
<i>Average delay</i>	$\frac{\sum BLO}{n_i}$
<i>Absolute deviation of order fluctuation</i>	$\partial_{io} = \frac{\sum  x_i - \bar{x} }{n}$
<i>Squared deviation of order fluctuation</i>	$\partial_{io}^2 = \frac{\sum (X_i - \bar{X})^2}{n}$

To see the behavior of different concepts we prepared different scenarios based on simple ordering strategies.

- NAM - no amplification
- PFO - perfect forecast

In the first scenario we played by a simple rule: every participant orders the exact amount of their incoming order. The aim of this scenario is not to collect safety stock and amplify the produced and delivered units of beer unnecessarily. (This scenario

was already presented in our previous article at the ICLST, 2013, Celje) The results are summarised in the next table:

**Table 2. Results of NAM BeerGame [6]**

	Retailer	Wholesaler	Distributor	Factory
<i>Maximum Backlog of orders</i>	8	8	16	16
<i>Average shortage</i>	1,33	2,0	3,17	4,0
<i>Maximum delay</i>	5	7	9	10
<i>Max. delay of the chain</i>	13			
<i>Average delay</i>	6,4	6,86	8,44	9,6
<i>Average delay of the chain</i>	4,85			

#### **Maximum Backlog of orders:**

This is the simplest indicator of the customer perspective; it shows the biggest shortage of each player in the 24 rounds. In this case the Factory accumulated 16 units of beers as backlog which is quite big, according to the maximum order of the customer (12 units) and considering the aim of this scenario is not to amplify.

It refers to one “symptom” caused by the bullwhip-effect: the inventory levels at different points of supply chains varying separately from the real customer demand. [6]

#### **Average shortage:**

From the customer’s point of view it can be really important to see how many missing units he needs to be prepared for in the case of delay. A good supplier has to see with his customer’s eye.

#### **Maximum delay:**

This indicator shows the number of the periods in which the players couldn’t satisfy their customers in the longest period.

#### **Average delay:**

It can be a crucial factor how reliable one company seem to the customer; they need to provide the lowest average delay as they can, to minimize the amount of missing units in one case of shortage.

#### **Average delay of the chain:**

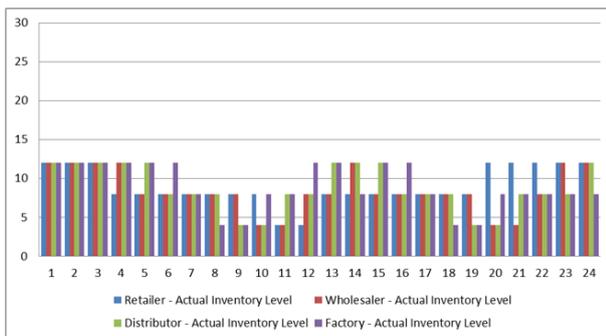
It shows the reliability of the supply chain. In those rounds where somebody couldn’t fulfil an order, we can expect 5 units of beers in backlog.

The second, the PFO scenario means we knew all the information about the future customer orders and the replenishment rule of the participant was to have in stock precisely the amount in every case they need to deliver in the next round. We wanted to examine this scenario, because most of the scientific literature suggests that the information sharing is the way to eliminate the bullwhip effect.

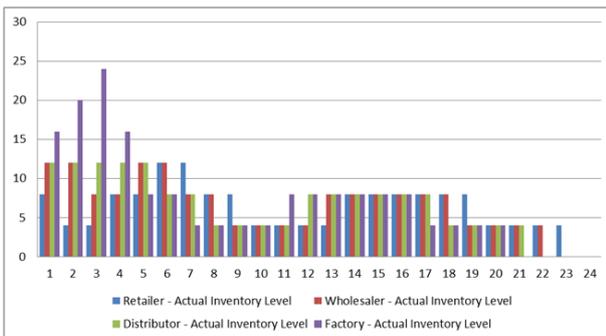
Thanks to the perfect information sharing we were able to exclude the shortages; everybody had the needed amount in stock, in time. The drawback of this scenario that without shortages all the equations we use to demonstrate the customer satisfaction and partner relations equal to zero. Comparing the other perspectives we can conclude PFO scenario to be more successful than the previous (NAM) reference. (The Table 3 shows the comparison of strategies by other KPIs and the inventory level is demonstrated on Figure 3,4.)

**Table 3. Other KPIs**

	NAM	PFO
<i>Global Total Cost</i>	1352	640
<i>Average Total Cost</i>	338	160
<i>Retailer Inventory</i>	216	152
<i>Wholesaler Inventory</i>	204	160
<i>Distributor Inventory</i>	212	156
<i>Factory Inventory</i>	216	172



**Figure 3. Inventory Level - NAM**



**Figure 4. Inventory Level - PFO**

## 5. CONCLUSION AND FURTHER RESEARCH

The BeerGame environment is excellent for training university students and expert from the economy to get cooperative and innovative skills in supply chain coordination. In the same time, during the trainings the importance of Balanced Score Card

methodology is coming from theory into practice and participants can get real-life experience about the construction and operation of logistics performance measurement systems.

Another important feature of the training came into highlight: we can examine different scenarios, replenishment rules, management tactics in a clearly defined environment. In the last period of the research we were working on some basic scenarios with simple regulations. The basic scenarios we created form the ideal cases of supply chain management actions and provide excellent indicators as reference scenarios.

We should put more emphasis on creating experience based input functions for the simulation.

## ACKNOWLEDGEMENT

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# DRP GAME: NEW TOOL TO ENHANCE TEACHING AND LEARNING IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT

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***Abstract:** This study presents a new logistics and supply chain management educational game called *DRP Game*, which enables players to cooperate within teams and practice the logic of distribution requirements planning (DRP) method. This game has been developed and applied at the Faculty of Organizational Sciences, University of Belgrade, as a supplement to traditional teaching about distribution channels and DRP topics within Business Logistics course over several years. The *DRP Game* is offered free and can be easily tailored by interested instructors. Meanwhile, the results of game usage evaluation showed that students were very satisfied with the *DRP Game* and that they would like to use more games like this in the teaching process. The results of this study are useful for both academics and practitioners interested in training and education in the field of logistics and supply chain management.*

**Keywords:** *game, distribution requirements planning, logistics, supply chain management.*

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## 1. INTRODUCTION

The educational institutions have a huge responsibility to prepare students for dynamic logistics and supply chain management (SCM) profession. They must continually analyse and question their study programs and ways of teaching in order to enable acquiring appropriate knowledge, skills and abilities to the future logistics and SCM professionals. Games usage in combination with other teaching approaches is one promising way to improve efficiency of courses related to the field of logistics and SCM.

In general, 'a game is any activity with at least one established objective and an element of competition among players' [3]. It places players into competition against each other or against standards [11], [3]. A game can be considered as an extension of simulation [12] and very often, a game comes out of simulation with the addition of some elements of competition [11], [3]. They can have some advantages over simulations such as determining the adequacy of existing structures, policies or procedures; bringing more effective communications; enhancing learning; preparing people for coping with future situations; generating

new ideas, and projecting uncertainty, according to the same sources. According to [12], games are more appropriate method than a simulation for learning and strategic-decision making in the macroscopic logistics and SCM environment. The using of games and case studies in addition to traditional lectures for teaching SCM is advocated by [13]. In [7] is pointed out that most logistics and SCM educators use at least one game, simulation and/or interactive exercise in addition to other teaching methods such as lectures and case studies.

Logistics and SCM educational games allow students (players) to play different roles, e.g. a logistics manager, a supply chain manager, a distribution network designer, an inventory manager, a logistics engineer, etc., in an environment 'without real risks' that consists of virtual entities, such as products, factories, transport vehicles, distribution centers, wholesalers, retailers, etc. There are a number of logistics and SCM games that can be applied in teaching and learning processes. They are diverse in terms of scope, topics, type, number of players, utilization costs, etc [3]. Therefore, they can be classified according to their scope from a microscopic orientation (such as some parts of a logistics system, such as a machine, transportation vehicle, etc.) to a macroscopic orientation

concerning a total supply chain, based on [12], [3]. The presence or absence of some logistics and supply chain topics can be related to the certain game. In terms of type, the logistics and SCM games can be classified as non-computer and computer games, and more concretely, as manual, software, and online games. They differ in number of players which can be included in the game and often the minimal and/or maximal number of players is limited. When attention turns to costs, they vary from free games to very expensive commercial games.

At the Faculty of Organizational Sciences (FOS), University of Belgrade, the logistics and SCM games have been employed as complementary teaching tools in courses of Business Logistics and Supply Chain Management. The Business Logistics course is compulsory and Supply Chain Management is optional in the undergraduate program Operations Management. The aim of the Business Logistics course is to provide students with knowledge and skills in the fundamental concepts and methods of logistics management. It is a one-term course taught in the fifth semester. The aim of the Supply Chain Management course is to provide the students with the understanding of strategic importance of supply chains in the global environment, and with the methods, tools, and activities necessary for efficient and effective SCM. It is a one-term course, taught in the eighth semester. In order to select and apply the most suitable games according to the requirements of these two courses the serious analyse of the 'market' of logistics and SCM games was conducted [3]. The lack of educational tools for actively supporting the topic about Distribution Requirements Planning (DRP) took us to the idea to develop a new game, named *DRP Game*. The aim of this paper is just to more closely represent this new logistics and SCM game, which we believe can be useful for interested educators.

The remainder of the paper is organized as follows. In the next section, a brief theoretical background about *DRP* is given. Then, a new logistics and supply chain management educational game called *DRP Game* is presented. The results of evaluation the *DRP Game* from two generations of undergraduate students are then shown. Finally, some concluding remarks are offered.

## 2. THEORETICAL BACKGROUND

*DRP* is a time-phased replenishment approach for determining finished goods inventory requirements within the distribution network and periodically

generating new shipment plans [4]. It is based on forecasting demand at the lowest level in the distribution network and consolidating demand information in reverse until the highest level in the network has been reached. *DRP* can be used across company boundaries as well as within them [14, p. 181]. The main purpose of *DRP* is to ensure that the right finished goods in the right quantity reach the demand centres (e.g. retail stores, distribution centres) at the right location and in the right time [8]. The potential advantages of using *DRP* are inventory reduction in the distribution network, better customer service, cost reductions and compatibility with other systems within the supply chain (e.g. Material Requirements Planning (MRP), transportation planning) [4]. On the other side, the disadvantages include relatively high implementation costs and system nervousness which can result in highly uncertain environments, according to the same source.

*DRP* systems use logic similar to those used in Material Requirements Planning (MRP). 'They generally function according to the 'pull' principle, although there are some *DRP* systems that function according to the 'push' principle. Pull *DRP* functioning can be explained by the following steps:

- 1) Identifying the projected requirements of the lowest distribution network levels by planned periods, according to the forecasted demand for items;
- 2) Generating report – schedule of the planned orders, with application of MRP logic, and issuing purchase orders on the next higher level within the distribution network;
- 3) Calculating the projected requirements by planned periods on a higher level, influenced by the orders issued by the lower level; and
- 4) Going back to the second step, until the highest distribution network level has been reached', [8].

*DRP* was developed by Andre Martin during the 1970s and 1980s. The first two implementations of *DRP* systems were in American Hardware Supply (currently a part of True Value) and Mass Merchandisers Inc (now part of McKesson) in 1983, also owing to Martin, according to data given in [6]. Further extension of *DRP* included planning of the important resources within the distribution system, such as warehouse space, human and financial resources, cargo vehicles, etc. The term used for such *DRP* extension was Distribution Resource Planning (*DRP II*). Today, *DRP* (or *DRP II*) is usually included as a module in the Enterprise Resource Planning (*ERP*) systems. In the last years,

Andre Martin together with his colleagues Mike Doherty and Jeff Harrop have been working on the development of wider extension of DRP known as Flowcating (see e.g. [9], [6], [8]).

In the educational environment, the MRP and DRP are important topics in courses related to logistics and supply chain management. Several educational games and software systems for supporting the learning of MRP are developed. For example, the “In-Class Manufacturing Game” [1], the “Lean Manufacturing Simulation Game” [5], the “HECOpSim” game [10], and the well-known software systems like “WinQSB” [2] and the “POM-QM for Windows” [15] which offer a module for processing the MRP data. On the contrary, the lack of educational tools for actively supporting the topic about DRP is noticeable. This was the main reason why we were developed a new game (named DRP Game) for practicing the DRP logic in the previous years.

### 3. DRP GAME

The DRP Game is a role-playing simulation for practicing the logic of Distribution Requirements Planning (DRP). This game enables students to experience DRP environment by playing different positions in a distribution network. The distribution network consists of one brewery which distributes products to several retailers through wholesalers (Figure 1). Each player is the member of team which gets and takes the role and responsibilities of one distribution network participants: brewery planning manager, wholesale purchasing manager or retail purchasing manager. The teams are distinguished by colour and at the beginning of the game each player needs to find his team members. Teams are competing in developing the plan of distribution requirements for a 7-day planning period. The members of team in the roles of retail purchasing managers have the task to release the »summary« purchase order for a 7-day planning period to appropriate wholesaler based on orders from known customers and demand forecasting. The members of team in the roles of wholesale purchasing managers have the task to release the »summary« purchase order for a 7-day planning period to brewery based on »summary« purchase orders obtained from retailers. The member of team in the role of brewery planning manager has the task to release the »summary« production order for a 7-day planning period to Judge (this role is envisaged for instructor) based on »summary« purchase orders obtained from wholesalers. The criteria for determining the winning team are: accuracy and time. The possibility

of getting the role of observer in the game is also anticipated, and the students-players in these roles have the task to release the ‘secret’ report to Judge.

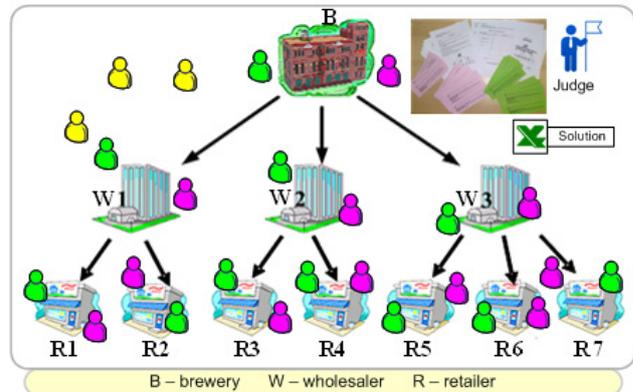


Figure 1. DRP Game environment

One game usually requires a five to ten minutes of presenting the rules of the game, about twenty minutes of actively playing and more than half an hour of discussion. The general prerequisite for this game is the players' previous knowledge of DRP logic and basic lot size models (Lot for Lot (LFL) and Fixed Order Quantity (FOQ) are mandatory). The instructor can create a number of variants of this game by changing the number of teams and/or number of members per team, the number of observers and/or the DRP problem.

The DRP Game is played with the use of the following paper based documents: DRP Game Instruction, DRP calculation tables, »Summary« reviews of orders from known customers and demand forecasting, »Summary« purchasing orders, »Summary« production orders and »Secret Mission Reports«. Solution for discussion of team results is provided as an MS Excel document. Diplomas and optional other prizes for the members of winning team are also anticipated.

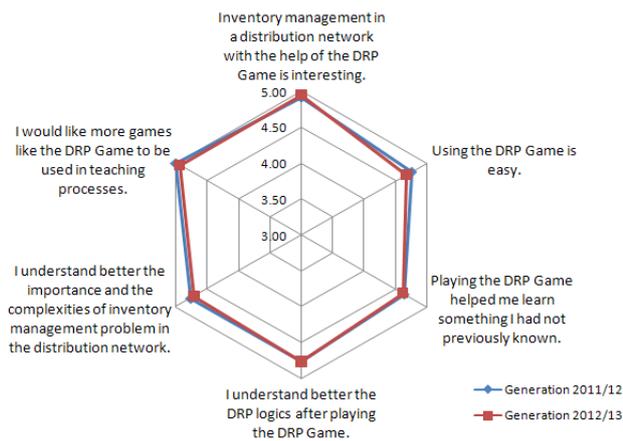
The DRP Game can be useful for supporting topics such as distribution channels, DRP, integrated MRP-DRP system and other similar topics. The DRP Game is available free of charge and all the files that are required for an instructor to apply this logistics and SCM game can be downloaded from <http://fon.fon.bg.ac.rs/~cvetic/drpgame.html>.

#### 3.1 Students' viewpoint of the DRP Game

The DRP Game has been used for active support to the DRP topic in the undergraduate Business Logistics course at the FOS for several years. Its evaluation was conducted during the winter semesters of 2011/2012 and 2012/2013. The post-game questionnaire consisted of two parts of statements, one for evaluation of the game and the second one for the evaluation of instructor. Students

were asked to rate their experience with playing the game on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The total of 25 students from one generation and 34 from another participated in the evaluation of the game. During this evaluation, the instructor was rated with very high scores and these results are omitted. This might be explained with the previously well established relationships between students and instructor.

The results of evaluation the DRP Game are presented in the form of a radar chart in Figure 2. Both generations of students (hereafter, G1 and G2) gave the highest scores to the statement that they “would like more games like the DRP Game to be used in teaching processes” (G1: mean (M) 5.00; G2: M 4.94, variance (V) 0.06, standard deviation (SD) 0.24) and that the “inventory management in a distribution network with the help of the DRP Game is interesting” (G1: M 4.92, V 0.08, SD 0.28; G2: M 4.94, V 0.06, SD 0.24).



**Figure 2. Results of DRP Game evaluation (mean values)**

Also, students were very positive about all other statements in relation to the DRP Game usage. The following two comments received from students are emphasized. “The game is great. All praise. It develops team spirit.” and “All the praise for introduction of such contents in the class!” Obviously, according to these results, learning and practicing of DRP logic were influenced by the DRP Game. However, these results should be taken with caution because it is possible that they were influenced by the fact that students knew that the game had been developed at the FOS.

### 3.2 Instructors’ viewpoint of the DRP Game

The DRP Game is a very simple game which helps students to practice the logic of DRP in an interesting environment. Usually, during the reading

of DRP Game Instruction some students are laughing when they come to the description of the roles of observer and Judge, and some of them look very confused with the rules of the game. After receiving other documents for playing the game, the common question from students is: “Can we freely walk in the classroom?”. Upon receiving an affirmative answer from Judge, some students quickly begin to form teams, while others sit in their seats and still waiting for someone to find them. As time passes, students with better knowledge of DRP start to help other teammates and check their results. When one team completes the game and submit the results to the Judge, the ‘little disappointed’ players from the other team/teams start to even more concentrate on the accuracy of their solution. Therefore, it could be said that this game can show some aspects of students’ nature in sense of prudence and competitive spirit.

When all teams submit their results to Judge, the observers have the opportunity to give the suggestion of winning team with accompanying explanation which includes comments on efficiency of achieving results, communication within a team, time, etc. Then, solution discussion starts from the lowest distribution network levels. As we moved closer to the proclamation of the winning team, the students increasingly cheer for their team and loudly comment. Sometimes, it is quite difficult to maintain order between different teammates in the classroom. After the end of the game, all students seem very satisfied.

The main disadvantage of DRP Game is time required to carefully prepare all needed documents. Any modifications in the number of teams and/or number of members per team, and/or the DRP problem required additional time for customization.

The best thing with the DRP Game, which we want to emphasize, is that since we apply this game in combination with lectures for supporting the topic about DRP, all students successfully solve tasks related to this topic on the colloquium and/or exam.

## 4. CONCLUSION

Games are a helpful and enjoyable supplement to other teaching approaches. Since the 1960s a number of logistics and SCM educational games have been developed in academic, military and commercial organizations. However, the lack of games for actively supporting the important topic about Distribution Requirements Planning (DRP) in the field of logistics and SCM was noticed, and hence a new game named DRP Game is developed.

The DRP Game is a role-playing simulation for practicing the logic of DRP which enables students-players to experience DRP environment by playing different positions in a distribution network. This game has been successfully used in the undergraduate Business Logistics course at the FOS over several years. The game is available free of charge to all interested educators in the field of logistics and supply chain management.

Some limitations of this study include small populations of students-players of DRP Game, the only one course at one faculty considered and evaluation conducted via only the post-game questionnaire. In our future work, the intention will be to examine the influence of this logistics and SCM game on students' achievements and provide the more comprehensive evaluation of the game from students' viewpoint. It is hoped that we will continue to further enhance and improve teaching and learning activities in courses related to the logistics and supply chain management.

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# IMPLEMENTATION OF STATISTICS TOOLS IN THE GRETA MASS PRODUCTION MODELLING ENVIRONMENT

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**Abstract:** *As a part of our LEGOstics plotting board series we've created the GrEta production simulation. In this creative learning environment all the actions are provided by participants – with flexible, dialectic (learning-by-doing) ways, focusing on evaluation results and the whole process of performance measurements. We are developing all these environments on the same platform: analysing and developing the processes according to the technology and real nature of logistics processes (warehousing, material handling, production and transportation). During the trainings the participants can experience the theory/curriculum of production – push, pull systems, kanban, lean thinking, bottleneck problem etc. In the actual state of the development we are focusing on the quality management. Using statistical tools can help us to see some correlations and contexts between the operations and the created results: the quality of products/services.*

**Keywords:** *LEGOstics, GrEta, Quality management, Learning-by-doing.*

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## 1. THE GRETA ENVIRONMENT

GrEta is a self-developed, non-official LEGO product, based on our intention to construct a relatively simple model, which can be built up differently and in totally flexible ways. GrEta car has 8 separate functional parts: chassis, wheels, engine, engine hood, seat, computer unit, cabin, lamps. The parts also can be assembled on several ways. The participants have a lot of possible strategies and production system structures, according to the decisions of the team based on the different personal attributes. The plotting board is basically a regular wooden board, which has been separated into four workstations. Between the workstations we situated four drawers for transportation. In the game the transportation has the highest priority, when a box (shipment) comes it always have to be unloaded and sent back to the previous participant to provide the possibility for the continuous material flow. We also developing an application, which is suitable for measuring the participants's gametime while playing with GrEta

plotting board. This automatic time measurement tool can give us information about the participants active/inactive periods, how long does a game lasts, when the drawers move. The software registers the results into a CSV file, where we can easily make graphs, and analysis.[4]



Figure 1. GrEta car [6]

## 2. QUALITY MANAGEMENT IN GRETA ENVIRONMENT

A quality management system (QMS) can be expressed as the organizational structure, procedures, processes and resources needed to implement quality management. Early systems emphasized predictable outcomes of an industrial product production line, using simple statistics and random sampling. By the 20th century, labour inputs

were typically the most costly inputs in most industrialized societies, so focus shifted to team cooperation and dynamics, especially the early signalling of problems via a continuous improvement cycle. In the 21st century, QMS has tended to converge with sustainability and transparency initiatives, as both investor and customer satisfaction and perceived quality is increasingly tied to these factors. Of all QMS regimes, the ISO 9000 family of standards is probably the most widely implemented worldwide - the ISO 19011 audit regime applies to both, and deals with quality and sustainability and their integration.

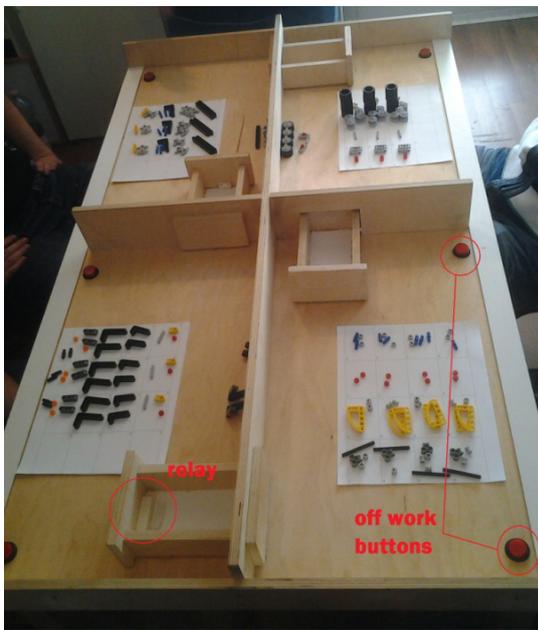


Figure 2. Electric Plotting board [7]

Quality – why should we study it?

Quality is everyone’s concern – it is a very real part of our daily lives. Leading scholars have recognized the inextricable synergy between organizational *excellence* and *quality*; these two key terms are synonymous. Excellence has been defined as „the overall way of working that balances stakeholder concerns and increases the probability of long-term organizational success through operational, customer-related, financial, and marketplace performance excellence“. Almost everyone would understand the concept of excellence – that is, the merits of striving to be the best – to excel in all walks of life.

The need is apparent. Satisfying that need is perhaps the most compelling reason why you should study this subject. The market for qualified quality professionals is growing and the applicable compensation and benefit packages can secure a comfortable lifestyle. Since quality is about

excellence and excellence is about balancing the need of all stakeholders.

From the literature of management sciences we know a lot of different tools used in quality management, for the GrEta environment we chosen six different methods to have an effective toolkit: Brainstorming, Check Sheet, Pareto Chart, Cause-and-Effect Diagram, Histogram, Scatter Diagram.

### 2.1 Brainstorming and Brainwriting

Structured and unstructured brainstorming is used by groups to verbally generate a large number of new ideas within a short period of time, normally with the use of a group facilitator to keep things moving along in an orderly fashion. When ideas are written down, rather than shared verbally, the technique is called brainwriting. However, the term brainstorming is generically used to refer to either technique.

The difference between structured and unstructured brainstorming/brainwriting is that the former requires each person in turn to contribute an idea when called upon; in the latter case ideas are spontaneous and no one is forced to participate. To be effective the following brainstorming rules of conduct should be followed.

- Free expression, called freewheeling, is encouraged by all,
- All ideas are welcome,
- Criticisms or critiques are strictly forbidden.

We use this tool since we created the training scenario; it’s a really important part of the training to discuss the ideas, experiences, problems and suggestions at the end of each round before we move on with the optimization.

### 2.2 Check Sheet

Before a problem can be analysed it needs to be understood. A check sheet, normally handwritten form on paper, is used to record raw data in a format that can be easily understood by everyone. In the GrEta environment usually the problems are not material, rather scheduling problems. Therefore on our checklist it’s wiser to note the movement what took more time than it should. For that we need to measure all the basic movements of assembly with our measurement tool – Elli3 – for elementary tasks. Based on the results we can create a list and define the frequency of in-time deviations.

### 2.3 Pareto Chart

The Pareto principle posits that only a few causes (the vital 20%) are responsible for the majority (80%) of problems. Improvement benefits can be

leveraged by focusing attention on the key issues (that is, the 20%), and while looking at critical factors this is not uncommon to discover and resolve many of the other lesser important problems by default. When check sheet data are plotted on a Pareto chart, the most important problems are revealed. It is customary to plot a pair of graphs – a bar graph that displays item percentages sorted in descending order, and a line graph that plots the cumulative percentage of items on the sorted list. These two graphs are then plotted on the same chart.

The figure below shows a sample Pareto chart, the problems are divided into 5 categories. This way the significant (vital) problems can be separated from the trivial ones. In this case this is clear that improvement efforts should target problems A, B and C. With this method in GrEta environment we can highlight the “*bottleneck positions*” regarding to the “*bottleneck movements*”.

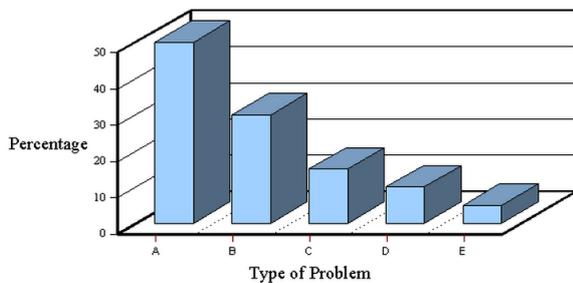


Figure 3. Sample Pareto diagram [3]

### 2.4 Cause-and-Effect Diagram

The cause-and-effect (CE) diagram is also called a fishbone diagram (due to its similarity to the skeletal structure of a fish), and „*Ishikawa diagram*” (in honour of its founder). Once a team decides which problem it wants to solve, possibly from a Pareto analysis, the CE diagram can help to identify candidate causes.

The CE structure is illustrated in the following figure. To construct a CE diagram, the problem, or effect, is placed in a box. A horizontal line is drawn from the box, and from the backbone angled fishbones are inserted corresponding to each main problem category. This forms the skeleton of the fishbone diagram.

Main categories can be anything relevant to the problem, but the typical ones include materials, methods, personnel, and machines. From each main item smaller bones are constructed for each candidate cause, and from these, smaller bones representing subcauses are drawn. The diagram can include as many sublevels as required to get to the root causes.

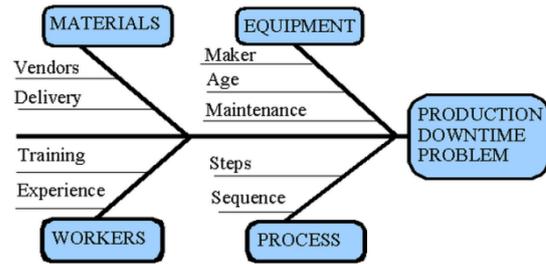


Figure 4. Fishbone Diagram Structure [3]

For example in the GrEta environment we can consider the “Process” box as the production in push system. The smaller bones can be the delays and idle time. Going deeper we can realise, if a position doesn’t have enough time to prepare its task before the next product comes, it would cause a bottleneck, and the whole process will stop, gets wrecked. With applying a controversial system (pull) the positions get the next semi-finished products when they are prepared for them so that the process can go seamlessly.

### 2.5 Histogram

A histogram provides a graphical picture of process output. Collecting raw measurements is meaningless unless the data can be organized in a way that aids discovery and analysis.

In our case we can measure the time between finishing the complete cars, or different operations, then classify them. That way we can see the dispersion of operations’ time consumption.

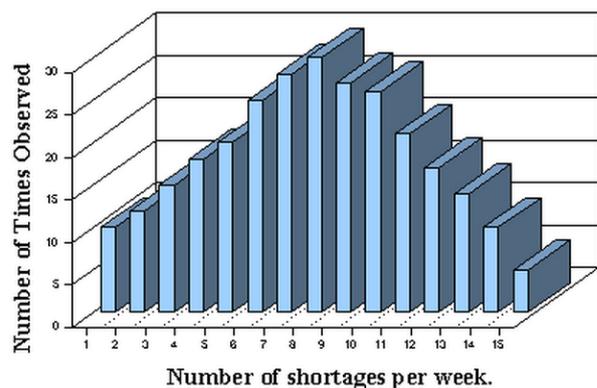


Figure 5. Sample Histogram – how performance measurement is distributed over time [3]

To construct this histogram, each of the data points should be assigned to class intervals. A bar chart can be then constructed by plotting the frequencies calculated in each class interval. The histogram provides an approximate picture of the process distribution.

## 2.6 Scatter Diagram

Like histograms, scatter diagrams aid in pattern recognition. A scatter diagram, also called a scatterplot, can be used to gain insights into the relationship between two factors. If a relationship is found, it cannot necessarily be inferred that one variable is the cause of the other; however, the scatter diagram can provide graphical evidence that the relationship is real and will provide some knowledge regarding the strength of the relationship.

A scatter diagram is constructed by plotting the values of one variable on the horizontal (x) axis, and the corresponding value of the other variable on the vertical (y) axis. A relationship between the two variables is evident if the resulting plot produces some non-random pattern of points. The strength of the relationship is determined by the variability of the cluster of points relative to a mathematical expression describing the association. A relationship can be linear or nonlinear.

The following figures illustrate some scatter diagrams that are linear, and below some nonlinear relationships.[1]

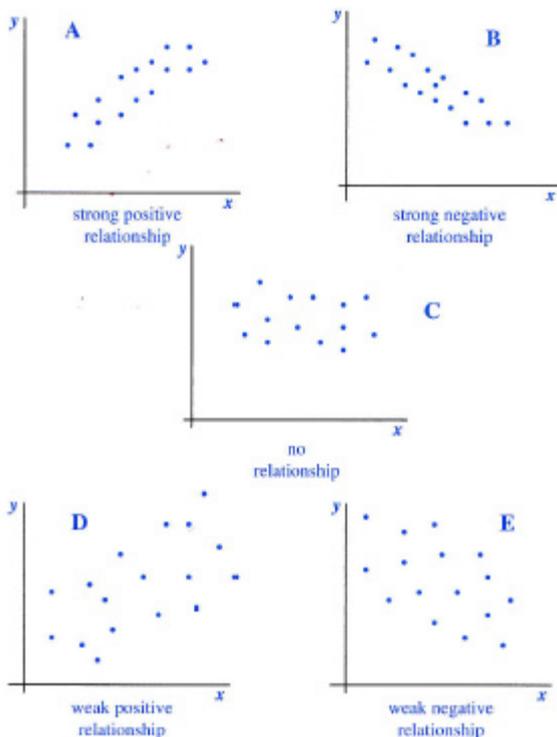


Figure 6. Linear relationships [1]

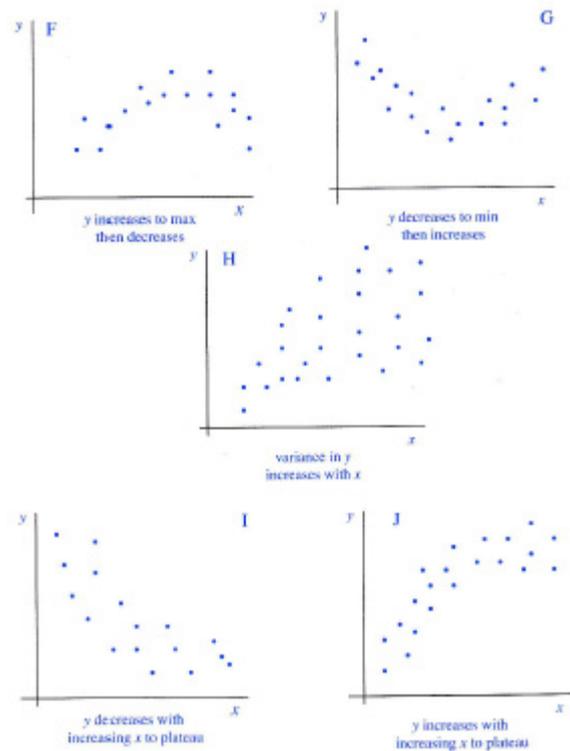


Figure 7. Nonlinear relationships [1]

## 3. CONCLUSION

We have lots of experience about the trainings, measurements and evaluation. The test results show that the developed automatic time measurement program is necessary and effective, on this way it is possible to log many state-variables. Participants can learn easily how a mass production system is working, and they can develop critical skills according to the preparation of decision making processes, negotiations, logistics process measurement and evaluation.

In spite of the fact that GrEta is a classical factory-type environment, it is possible to extend it on the supply chain context with defining specific lead times and order batches for material supply (box movements). Although experts consider logistics operates within one corporation and supply chain management deals with the collaboration of separate corporations from our point of view these are not completely different fields. The synchronised, well balanced production processes are equally important as synchronised and well balanced supply relations. The methods we present for production planning in the frame of the trainings are also capable to demonstrate the interactions in the supply chains.

During the training it is possible to put emphasis on the importance of logistics process re-engineering

and develop the critical skills of participants to be able to:

- recognize critical factors of production
- construct appropriate performance measurement systems
- support the decision making process of system developments

In our paper we presented a possible way to teach and understand quality management and some sophisticated statistical tools to develop a well-balanced production environment.

#### ACKNOWLEDGEMENT

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## INTERACTIVE TRAINING AND MODELLING ENVIRONMENT IN WAREHOUSE LOGISTICS

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***Abstract:** Warehousing processes contain several hidden opportunities for cost-effective process development. Cost and performance optimization is possible with the reengineering of algorithms, assignment decisions, scheduling and sequencing solutions without infrastructural investments. One of the most objective and cost-effective ways of development is modelling in validated and flexible simulation environments, which require and also enable an active cooperation with our industrial partners. In our essay, we introduce an interactive training and modelling environment, which is developed in Szabó-Szoba R&D Laboratory at Széchenyi University Győr. This is a part of our innovation cycle by synchronizing plotting board and computer-based solutions. Besides providing continuous feedback about the measured processes, this environment allows us to prepare and evaluate alternatives along with our partners, and which we can use later on for detailed simulations.*

***Keywords:** Warehouse, plotting board, modelling, simulation.*

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### 1. IMPORTANCE OF MODELLING

The main challenges of modern logistics and supply chain management are providing high level quality service for customers according to the ever-growing and ever-changing demands, optimizing low series production and distribution in various environments, managing stocks in lean and agile production systems, eliminating the bullwhip effect, applying different trade-off solutions for minimizing infrastructure investment, distribution and warehousing costs and maximizing capacity utilization. The wide variety of products, the challenges of fluctuating demand, the appropriate inventory management and the application of modern production and distribution strategies require flexible innovative thinking and special management skills from experts: to be able to construct and manage an effective, well-balanced manufacturing and distribution process in supply networks. [5] [6]

The learning by doing method, based on personal experience (dialectic approach) is able to support education and trainings to enhance these innovative

and cooperative skills. The main purpose of our learning by doing simulation projects in Szabó-Szoba R&D Laboratory is to construct special real-life environments in the field of logistics: modelling the product and information flow in a supply chain, taking care of shipments, material handling and order picking processes of a warehouse or a factory. [1]

In these creative environments all the actions are provided by participants – focusing on the evaluation of the results and the whole process of logistics performance measurement. During the learning by doing trainings participants acquire practical knowledge and develop innovative skills which makes them able to construct, observe, design and re-engineer sustainable and efficient logistics processes. [1]

Modelling has a key role in logistics system design and development. By constructing models and simulations it is easier and cheaper to discover problems and bottlenecks of logistics processes. Furthermore, modelling is an objective method for finding optimal and adaptive solutions, or to test the available alternatives. [2]

The most popular modelling method in daily practice is computer simulation. The WaNda warehouse and distribution plotting boards and simulation equipments provide an innovative approach for participants, and allow them to get real-life experiences about warehouse activities on the learning by doing way. [2]

Generally, both the plotting board and computer based simulation solutions have their own advantages and disadvantages. Our simulation equipment synchronizes the two modelling solutions mentioned above, by allowing the users to model warehousing systems and problems, to collect alternative solutions, to measure and evaluate the performances and results.

Measurements are highly important and essential tools during WaNda training simulations, since they give the possibility to evaluate the defined and tested alternatives.

## **2. PLOTTING BOARD AND COMPUTER BASED MODELLING**

[1] The plotting board modelling methodology is constructed to demonstrate simplified processes and layouts based on real systems, algorithms and databases. These instructive environments support brainstorming methods and help the participants to generate various ideas and alternatives. [2]

[2] The physical nature of plotting boards has significant advantages. In modelling environments, it is possible to compare different layouts, rack settings, palletizing problems, capacity utilization, routing, storing and order picking algorithms, thereby the participants are able to perform several alternatives by hands without time-consuming programming requirements. From another point of view it is possible to compare the efficiency of different complex strategies after the analysis of numerous cases. It is very time consuming, so impossible to perform in frame of trainings.

Computer simulations make us able to model complex logistics systems based on algorithms, mathematical and statistical methods, while parametric structures and refreshable databases allow us to synchronize the set-up model with the actual project. The system continuously collects statistics and generates charts, which provide a basis to compare the alternatives. [2]

In our essay we introduce our innovation-cycle which enables us to synchronise plotting board and computer based simulation solutions.

## **3. THE WANDA PLOTTING BOARD MODEL**

WaNda (Warehouse aNd Distribution) is an interesting and representative model designed for logistics students and training participants to learn and understand relations and coherencies in supply networks and warehouses. Besides of it's educational value, it can also be used as an industrial application. Operational efficiency of the companies is strongly affected by the designed decisions, but they can be very expensive or impractical to change once the warehouse is built. The WaNda environments are able to demonstrate the impact of these decisions on the overall warehouse performance. [2]

The WaNda interactive equipment is available for the following functions:

- Educational trainings: to demonstrate warehousing problems, tradeoffs and searching solutions on the learning by doing way
- Industrial and educational trainings: to demonstrate the importance of modelling and optimization
- Interactive cooperation with industrial partners: to understand the processes and best practices of the actual system. The participants or employees may realize the problems and bottlenecks of their own system. In addition, they decide the further cooperation in Logistics Process Reengineering projects and define the further way of the innovation process
- To support brainstorming processes: The consultants and partners collect and immediately evaluate possible alternatives, which makes them able to construct a detailed modelling environment, and make decisions
- To demonstrate defined solutions for directors, managers and employees: The interactive way of demonstrating results, and they can get familiar with the upcoming processes

## **4. INNOVATION CYCLE**

The measurement process is a critical part of the innovation and development project, which requires continuous feedback between daily operations and managerial decisions in the frame of round-by-round consultancy cycles.

The measurement and evaluation of a warehouse is usually the first step of the innovation processes,

where the deep knowledge of the developed system is essential. Sometimes the measurements started after interactive training, where the importance of innovation is realized. The main aim of this previous training is to get to know the actual solutions, processes, best practices and problems together with the partners. Given the opportunity - before the measurements occur -, we start the process with an interactive training, where the importance and the goal of the innovation is defined. The main goal of this training is to become familiar with the processes, best practices and problems of our industrial partners.

During the innovation process, the interactive training and modelling plotting board are synchronised with a computer simulation, which enables active cooperation between the consultants and partners.

During the detailed modelling processes the consultants make detailed computer based simulations based on the previously prepared and evaluated alternatives. These models are constructed with real scaled layouts and are running with detailed programmed algorithms, which can test long time intervals and computationally intensive solutions. Furthermore, these computer-based simulations enable us to automatically generate all kind of statistics to compare alternatives.

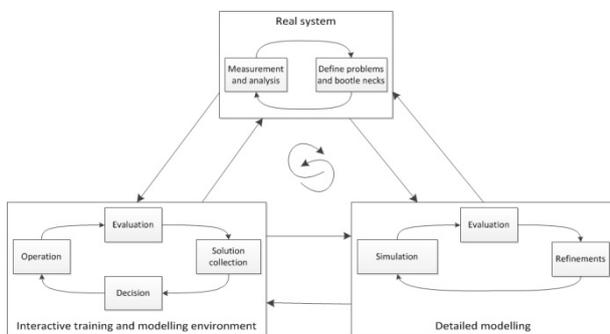


Figure 1. Consultancy cycle of innovation [3]

The innovation and development projects are never linear processes. They require continuous feedback and round by round development. Each consultancy cycle (Figure 1) element has special added value for the logistics process re-engineering methods and has two-way connection with every element. According to findings or developmental actions it is necessary to return to the measurement phase to get detailed results about the impact of changes. The development and the fine-tuning processes are impossible without continuous round-by-round tests and feedbacks. [3]

The following chapters will describe the details of the consultancy cycle elements.

#### 4.1 Real warehouse operation

The first step of each innovation process is the measurement of real-life physical processes and the analysis of the measured data and the possible operational databases. First of all, the consultant should become familiar with the partner's processes and logistics system, what usually happens during meetings, industrial visits and interactive trainings. [3]

Based on the previously acquired information, our Elli3 measurement tool will be customized to actual system. The innovation team defines the required measurements of the physical processes and the workflow of the measurement process.

Elli3 is an Android based application developed in Szabó-Szoba Laboratory for monitoring the time request of all pre-defined operations with automatic time stamps (Figure 2.). The examination of the workflow display-interface is adapted to the pre-defined actions appears to be measured - the assessor will tap to activate each key, and the device records the sequence of events with timestamps. [4]

By using our Elli3 tool we can discover several hidden parameters of product and information flow. Based on the results and analysis we can classify the main features of the operations and the product structure.

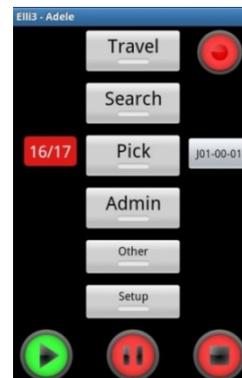


Figure 2. Elli3 screen for monitoring order picking processes [4]

During the testing process of the adapted Elli3 system, the team collects information about the processes and about refining the measurement application and the process itself. The measurement cannot influence the processes, the main goal is to strictly remain observers, which enables us to end up with objective and relevant data.

The measured data and experiences needed to be analysed between measurements, since observers have to recognize how much further data they need until the first analysis.

The first step of the analysis is to collect the latest documents of the real database to complete the

measured data. Based on data sources and personal experiences the innovation team defines the possible bottlenecks and problems.

#### 4.2 Interactive training and modelling environment

The next element of this innovative consultancy cycle is to collect and evaluate alternatives in simplified and synchronized interactive modelling environment (plotting board and computer simulation). Several possible solutions are tested and evaluated in the set-up analogue model, and only the relevant alternatives reach the stage of detailed simulation.

The operation in the interactive environment starts with the analogue version of the actual processes. After the first operation round they evaluate the process based on personal experiences and automatic measurement of the system. They define the problems and start a brainstorming to collect solutions. Then a decision is made and the changes will be implemented into the model. The participants test the new solution and start over the innovation cycle of the interactive environment. [3]

We have developed previously defined training environments, what can be used in formal education and in industrial trainings as well. One of these environments, the WaNDa Ruta module is focusing on the most expensive warehouse operation: the order picking process. Participants of this training recognize and realize the complexity of order picking strategy development, and the related resource needs as well. The environment is very simple; easily practicable in a normal university classroom. Only 24 regular plastic boxes are needed for the storage of LEGO parts serving as products. In the frame of the training we usually have 8 participants (order picking operators) and some observers. The 24 types of products have different colours and sizes, and there is only one product type in each box. [1]

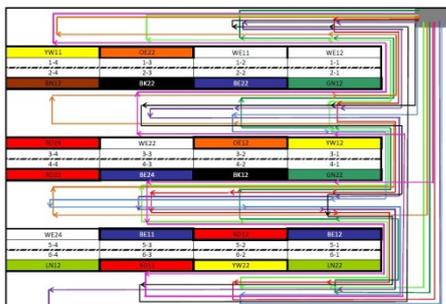


Figure 3. Routing in WaNDa Ruta [1]

Reducing of travel needs is possible with the modification of product arrangement: for example

by moving the fast velocity goods near the entrance of the corridors, however, traffic jams may occur more frequently in that case. The optimization process requires the synchronization of travel reduction by product arrangement modification and picking sequence modification according to the time request of different tasks. Figure 3. shows visual documentation of a routing solution on the WaNDa Ruta layout. The lines show the operators' picking route.

In further rounds participants are able to form the algorithms for zone picking strategy –on that way, travel needs and traffic jams may be reduced, but usually more workforce is required. [1]

#### 4.3 Detailed modelling

During this step of the innovation process, the consultants build detailed computer based simulation model for each defined alternative. This model is immensely complex, it is based on the real scaled layout, real resource capacity, real amount of storage capacity and so on. Furthermore, the computer-based simulation enables us to run the model in a long-term interval. So the detailed modelling environment is good for seeing how the defined solutions will work in the real industrial system. [3]

The detailed simulation models make it possible to define alternatives, implement and evaluate new ideas, what results a new cycle in this level of the innovation process.

#### 4.4 Global innovation process

The defined alternatives are evaluated and refined in detailed simulation models. The new solutions, defined by the computer based simulation, are tested and evaluated in the interactive plotting board environment. This cycle keeps going until the partner and the consultants decide that the defined solution is ready for the real operation.

After the implementation process, the upgraded real system is measured once again to check the efficiency and effects of the found solution. After that, the problems and the bottlenecks are defined again and this process is repeated continuously later on .

This interactive environment makes us able to demonstrate system changes for operators, managers and directors as well (usually, managers on a higher hierarchy level are not involved in the development processes). This function usually results in a better acceptance rate, which means that the colleagues will believe in the solution and they will support the implementation process. [3]

Figure 4. shows the computer based simulation model of the WaNDa Ruta environment, which was

used to measure the distances in different order picking routing variations. [1]

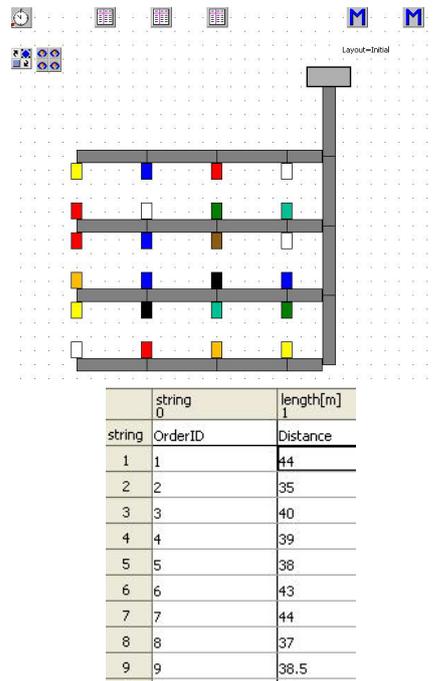


Figure 4. Computer simulation model of WaNDa Ruta [1]

## 5. CONCLUSION

In our essay we have presented our innovation cycle, as a possible frame and tool to develop logistics processes, moreover, we demonstrated the benefits of an interactive training and modelling environment in the frame of WaNDa Ruta.

These innovative consultancy methods support the continuous Logistics Process Reengineering projects in active cooperation with the partner. The system, processes and problems are modelled in an interactive plotting board model, which is based on the measurement of the real processes. The possible alternatives are collected and evaluated in the environment together in active cooperation with partner. The defined alternatives are refined and compared in detailed computer based simulation models. Continuous feedback and round by round development enables us to create implement a detailed and evaluated solution.

The described interactive training and modelling environment synchronise our plotting board and

computer based modelling environments, making us able to evaluate possible alternatives without programming.

The environments are developed continuously, and we are able to simulate and model several logistics problems and processes, to develop alternatives and to construct solutions

## ACKNOWLEDGEMENT

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## MEASUREMENTS WITH TRAFFIC COUNTER IN CITY LOGISTICS

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***Abstract:** City supply is one of the most highlighted topics in modern logistics. The main goal of research activities is consolidation and reduction of transport needs, lowering energy consumption, air and noise pollution, etc. The goal of our Tracy R&D Project is to invent an appropriate, flexible and low-cost traffic counter tool to support scientific research, decision making processes and the evaluation of actions made by city authorities. In our essay we present possible applications of the Tracy system.*

***Keywords:** City supply, traffic counting, measurement.*

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### 1. IMPORTANCE OF THE TRAFFIC VOLUME IN CITY LOGISTIC

There are many topics appearing in the scientific literature related to city logistics research like efficient supply chain, improved infrastructure and reduced logistics costs. Topic of economy and feasibility means growth in service, sector attraction, investments and new jobs. Topic of urbanization covers efficient and reliable supply and sustainability. The topic of traffic means less trucks, lower congestion, intelligent routing and higher truck utilization and the final topic, environment, covers improvement of life quality, noise reduction and air quality improvement.

Taniguchi et al. defined City Logistics as “the process for totally optimising the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy.” [5] [6]

Reference [2] states that City Logistics aims to reduce the nuisances associated to freight transportation while supporting the sustainable development of urban areas. It proceeds generally through the coordination of shippers, carriers, and movements, and the consolidation of loads of

different customers and carriers into the same environment-friendly vehicles.

Most authors describe city logistics in the frame of transportation or freight delivery. Reference [3] stated that logistics is vital to the life of cities and their residents. It is a major provider of wealth and a source of employment. Large logistics facilities, serving national and international markets have become a crucial element of dynamic metropolitan economies.

The next definition that comes close to what we are researching was stated by Reference [1]. According to that “City logistics is that part of the supply chain process that plans, implements, and controls the flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customer’s requirements”. The logistics associated with consolidation, transportation, and distribution of goods in cities is called city logistics. From a systems point of view, city logistics consists of many subsystems involving different stakeholders namely shippers, receivers, end consumers, transport operators and public administrators. The end-consumers are residents or the people that live and work in the metropolitan areas. Shippers (wholesalers) supply good to the receivers (retailers, shopkeepers) through transport operators (or

carriers). Administrators represent the government or transport authorities whose objective is to resolve conflict between city logistics actors, while facilitating sustainable development of urban areas.

The existing studies on city logistics planning can be mainly classified into (a) survey based approaches, (b) simulation based approaches, (c) multi-criteria decision making based approaches, (d) heuristics based approaches and (e) cost-benefit analysis based approaches [1].

In our paper, we are mainly focusing on the traffic point of view and on-field research. As Reference [4] stated, city logistics is about routing and scheduling logistics operations in urban areas. Concerning transportation, it seeks for approaches allowing for fast, accurate and reliable pickup and delivery operations as conducted by parcel services or waste disposal services. Nowadays, city logistics service providers have to consider dynamics within logistics processes, e.g., shorter delivery times, higher schedule reliability and delivery flexibility. Furthermore, service providers compete against other road users for the scarce traffic space of inner cities. In conurbanisations, traffic infrastructure is regularly used to capacity.

Realistic travel time estimations for the links of the traffic network are one of the most crucial factors for the quality of routing, since travel times in road networks heavily depend on network load. Network loads in urban areas are highly fluctuant with respect to different network links and times of the day, resulting in traffic jams. Hence, city logistics routing cannot rely on mere travel distances. For the most part, a single travel time value per link, as provided by today's digital roadmaps, only insufficiently represents the traffic situation. City logistics routing requires time-dependent travel times capturing load fluctuations for each network link. [4]

Travel time determination is a long established field of research. Traditionally, travel times have primarily been of interest in the context of modelling traffic flows and quality. The process of travel time determination consists of two basic steps. First, traffic flow data is collected empirically.

Then, the collected data samples are analysed and extrapolated in terms of traffic flow models providing travel times. The collection of traffic flow data is usually carried out by stationary sensors or by manual short-time census. Traffic flows in urban road networks are highly fluctuant with respect to different network links, times of the day and day of the week. In order to derive travel times for city logistics, area-wide data collection is necessary. [4]

Data analysis is usually carried out by parameterizing data flow models by collected data samples, resulting in speed-flow diagrams or daily curves of traffic flows. However, traffic flows on urban main streets are subject to a large variety of influences leading to modelling obstacles. A detailed reconstruction of travel times from traffic flow samples is complex. In sum, the provision of reliable travel times for city logistics routing is a challenging task and valid approaches are rare. [4]

## 2. TRACY ANDROID APPLICATION

The measurement system we constructed is an essential part of the modelling and simulation process, what makes us able to realize problems and bottlenecks, to generate input parameters and to validate the designed model.

Although measurement and monitoring has a key role in the innovation process, these activities usually got little interest. Many possible solutions are available from in-built recognition systems and video-observation to paper-based handwritten applications. The widely used traffic counter systems and methods have many disadvantages, like time demand of the data digitalization or huge installation cost.

The Tracy System was developed in Szabó-Szoba R&D Laboratory, Győr under the Android platform, running on tablets or smart phones. The goal was to develop an innovative traffic counter system, which can replace the old paper based systems. The data collection is much more exact and data processing is easier. There are no special logistics skills required by the observers, however, the application is powerful enough to have the capacity of gathering sufficient data.

The Tracy system is flexible and modular, observers able to measure different vehicles with different focus, different locations (from crossroads to roundabouts and traffic outbreaks), and we can perform special measurements (e.g. how many people are in the car, the cyclist wears a helmet or not). The system saves all the data with a time stamp, which allows us to analyse the time distribution of the traffic, and is able to record audio comments may special or unpredictable events occur. This system makes us able to monitor the time periods between the vehicles and we can also follow the daily traffic distribution.

Data gathered with Tracy can be used for different purposes such as recognizing the traffic flow on different points, crossroad's load and maximum capacity of vehicles on a certain road.



Figure 1. TRACY – FLOW screen capture

### 3. CUSTOMIZED SOLUTIONS WITH TRACY

In the near future, we are planning to convert the Tracy into a product line. The program can be used for numerous types of measurements on the road or railroad. The Tracy system covers all fields of transportation, and it is possible to customize the processes according to the field we need to measure. All of the sub-applications have the same advantages as the TRACY – FLOW, the only differences are the fields of studies and analyzations.

#### TRACY – FLOW

The Tracy flow is a cross-section traffic counter, with the function to distribute the vehicle categories and timestamps on each data input. The buttons on the screen are the official vehicle categories.

#### TRACY – BIKE

The Tracy bike is a measurement system, which concentrates on observing cyclists, with the focus on safety equipment, and rental bike usage. The buttons are customized according to the observation, therefore the followings: whether the cyclist has lamp, wears a helmet and vest or is it a rental bike or not.

#### TRACY – CARGO

The Tracy Cargo is a cross section observation platform similar to Tracy Flow, however, it focuses on cargo vehicles, such as different types of trucks, vans, and other types of commercial vehicles. The buttons are specified for cargo vehicle categories.

#### TRACY – FLT

FLT is the abbreviation of Fork Lift Trucks. The application is designed for warehouses and factories to monitor the fork lift truck traffic. These measurements may also be used to support WMS. With the Tracy FLT we are able to record forklift truck types, directions, and whether they are empty, half- or fully loaded.

#### TRACY – TRAINAPPROX

We can measure the passenger distribution in each section of the train from the pathway of the railway station. The observers check the train sections through the windows and choose a category from the previously declared ones. The pre-designed buttons are connected to the train capacity utilization categories.

#### TRACY – TRAIN

With the Tracy train, observers are measuring the passenger distribution at each door (e.g. how many passengers get on and off at a given railway station). The buttons indicate the doors (1, 2, 3, 4), and the number of get on or get offs.

#### TRACY – BUSAPPROX

We can measure the passenger distribution on buses from the pathway of the bus stop. The observers check the bus seats through the windows and record it through the previously declared categories. Buttons are connected to the bus capacity utilization categories.

#### TRACY – BUS

We can measure the passenger distribution at each door. We can measure how many passengers get off and how many get on at a given bus stop.

### 4. CASE STUDY

To test the Tracy system in a real-life environment, we measured the traffic flow in the city centre of Ljubljana. Logistically, the city is very unique, with only 7 roads leading to the city core, which is full of bars, restaurants and shops in needs of daily supplies. We set up a hypothesis that the number of delivery vehicles –especially during business hours - may cause traffic jams or congestions inside the city centre. In this chapter we are presenting our results we got using the Tracy – FLOW system.

During weekdays, numerous delivery vehicles enter the centre, in addition, there are few vehicles taking care of maintenance. Mails are delivered by bikes or motorcycles (in Tracy, we considered bikes

and motorcycles as one type of transport), however, larger packages are still delivered by cars or small vans. Delivery to the stores or restaurants within the city core is executed by different logistics companies or owners of the places, which means, that there is a huge number of cars or vans driving into the city centre. Although the city centre is meant to be a pedestrian-only area – closed by automatized platforms –, as we can see, there is still a big amount of traffic inside the limits (marked with red on Figure 2).

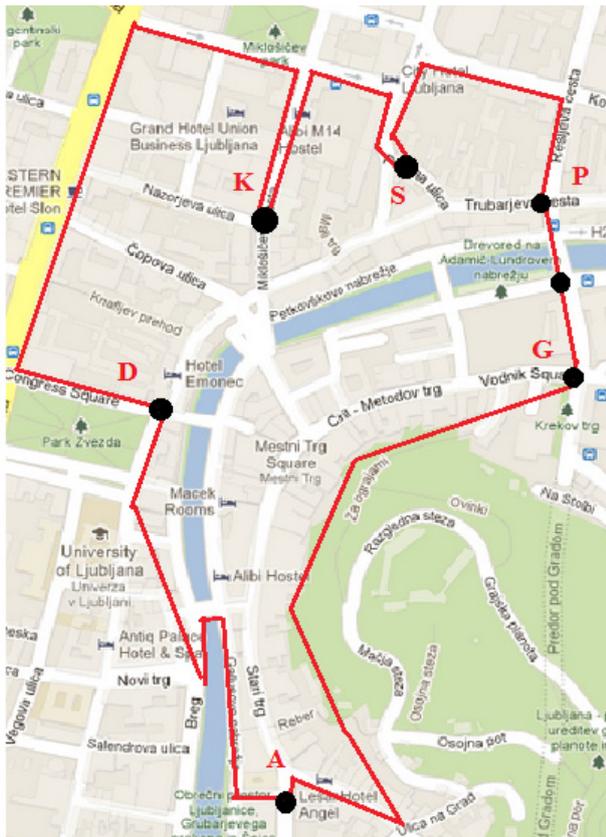


Figure 2. Observers in the city centre

After defining the main outbreaks (D, A, G, P, S, K) we measured the number of vehicles entering the city centre. Our goal was to test the hypothesis mentioned above and to gather sufficient data to – if our hypothesis proved to be right - propose possible solutions. Measurements were made in the morning (from 6.00 AM to 8:00 AM) because that is the time of the delivery peak. We measured the incoming traffic on the 7 different measuring points defined above. In this case, we put our focus only on van distribution.

Considering congestion and waiting time problems a lot depends on the arrival time of the delivery vehicles. As seen on Figure 3 there is a gap between 6 and 7 (10-40 minutes) and the constant 15-20 vehicles / 10 minutes level arrive after 7:30.

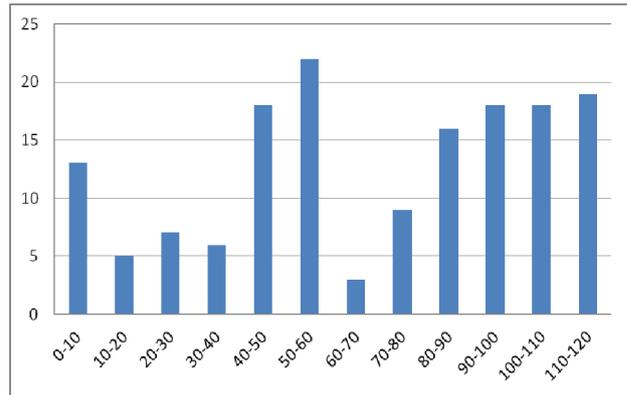


Figure 3. Distribution of Van arrivals from 6 (0) to 8 (120) AM

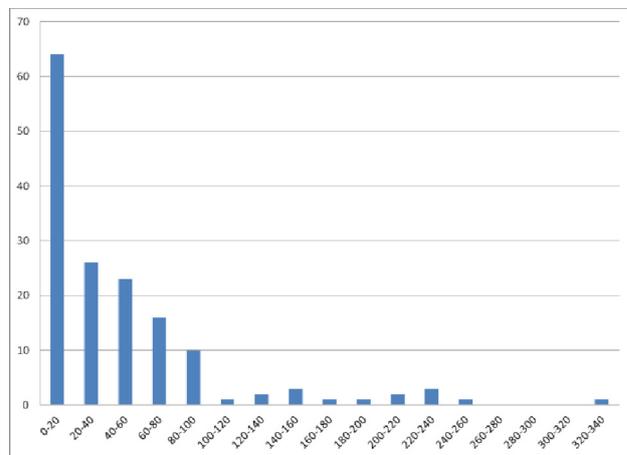


Figure 4. Distribution of time (seconds) between Van entering

In addition, we decided to focus on the time distribution between the vehicles entering the city centre. During the rush hours we recorded more than 60 arrivals in less than 20 seconds after each other (cumulative data, all entering points included) In spite of the fact that there was no serious congestion during the measurement we can highlight that there is a need for more accurate city supply planning and re-designing discussion.

## 5. CONCLUSION

The Tracy system is a flexible and adoptable framework which enables us to easily record data and additional information about wide variety of traffic and passenger flows. The customized Tracy applications are under continuous development in our laboratory, with the goal to cover every field of traffic measurements and support logistics decisions or re-designs.

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## THE BENEFITS OF MANUAL MATERIALS HANDLING WEB-BASED EXERCISES

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**Abstract:** *Scientific evidence shows that effective ergonomic interventions can lower the incidence and severity of musculoskeletal injuries caused by Manual material handling (MMH) tasks. Thus, teaching ergonomics must include both theoretical and practical exercises. Many online applications provide valuable user interface with a list of common MMH tasks. The calculator produce a number- percentage of individuals in the general population that could perform tasks without over exertion (the task which could be performed by 75 % of women, represents low-risk activity, while if the task can be performed by less than 10 % of men, it indicates high priority for task redesign) based on the NIOSH Lifting Equation. The advantages of the online application include capability to realistically simulate industrial work, having knowledge of how to perform planning in Warehouse management systems, and design jobs to allow sufficient rest for workers resulting in health improvement, psychological comfort and economic benefits.*

**Keywords:** *Manual material handling, NIOSH Lifting Equation, Lifting Calculator.*

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### 1. INTRODUCTION

Material handling is a necessary, but wasteful and expensive activity in manufacturing and distributing. In most operations, material handling can account for 30-75% of an item's total production cost [5]. Moreover, in a typical manufacturing company, material handling accounts for 25% of employees, 55% of all factory space, and 87% of the production time [3].

Despite the tremendous advances in technology over the last thirty years, a significant portion of industry routinely handles materials without the benefit of ergonomic assist equipment or devices. As a result of this, lower back disorders and even disability continue to be a primary source of loss. Although the basic concept of ergonomics has been around for many years, the skyrocketing costs and the human suffering associated with lower back injuries and cumulative trauma disorders [8] has made ergonomics a major topic of interest today. Ergonomics, the science of designing work to fit the capabilities of workers, can be instrumental in improving a company's productivity. Ergonomics will continue to be a major opportunity for the material handling industry and to planners of manufacturing, warehousing and distribution systems. Proper ergonomics in these systems today

increases production and quality along with decreasing medical costs, injuries, labour turnover and absenteeism [15]. These are contributing factors to the material handling industry's sustained leadership in the global market. Effective training is a key in delivering this type of workforce.

Injuries related to lifting are among the most disabling and costly of all workplace injuries, according to the 2012 Liberty Mutual Workplace Safety Index [18]. NIOSH (National Institute for Occupational Safety and Health) developed a tool used by occupational health and safety professionals to assess the manual material handling risks associated with lifting and lowering tasks in the workplace. The Lift Calculator, developed by NIOSH, has been used by employers and safety professionals for more than 30 years. For the last decade, companies such as Humantech [19] have used Excel spreadsheets to perform the calculations. The company's clients, who include distribution companies, auto suppliers, and heavy equipment employers requested an easier way to use the calculator. Now, an ergonomics company has created an application raising the NIOSH program to the next level of technology. Companies looking to reduce lifting-related risks to their employees can now use their smartphones or computer tablets.

## 2. ONLINE AND MOBILE LEARNING

Recent developments in information technology and telecommunications call for a serious reconsideration of the actual training methods and provide a wide opportunities for developing a new educational methodology. The main accent in development of both training and educational methods is put on using simulation techniques in developing new teaching material such as simulation-based case studies, simulation games, etc [14]. New training and educational methods like e-learning, m-training and any web-based learning become more and more popular.

Of the many different forms of ICTs, mobile phones are thought, for several reasons, to be a particularly suitable tool for advancing education in developing regions. They are the most prevalent ICT in the developing world, and their penetration rate is rising rapidly. The portability of mobile technology means that mLearning is not bound by fixed class times. MLearning enables knowledge acquisition at all times and in all places, during breaks, before or after shifts, at home, or when in motion. The ubiquity of mobile phones, moreover, means that educational services can be delivered with learners' existing resources. In as much as mobile technology presents a less cost-prohibitive medium for learning, it represents an important avenue by which to reduce the gap between the haves and the have-nots in contemporary society where access to knowledge and information is increasingly important [16], [9]. MLearning also facilitates designs for authentic learning, meaning learning that targets real-world problems and involves projects of relevance and interest to the learner [6], [4].

The new learning is personalized, learner-centred, situated, collaborative, ubiquitous, and lifelong. Likewise, mobile technology is increasingly personal, user-centred, mobile, networked, ubiquitous, and durable [12]. The literature indicates that the benefits afforded by this convergence should exert a positive impact on educational outcomes.

The applications used in mobile learning generally focus on brief interactions of perhaps several minutes or less, using simple navigation and graphics to accommodate multiple screen sizes. Such applications enable the quick review of information rather than prolonged or deep learning-as such, they are better suited for activities such as a status check, a request for just-in-time information, or as a student response tool in the classroom. Some exercises contain collaborative elements or game play, employing a variety of tools like social

networking, calendars, customized calculators, simulations, or augmented reality. As learning management systems adapt to the mobile platform, m-learning may become a common tool for exploration by tech savvy faculty. The use of mobile devices seems a natural fit for distributed learning and field activities in that handheld technology can not only accompany the learner almost anywhere but also provide a platform that is rapidly evolving and always connected to data sources.

Many people in the not so distant future will start to see the mobile phone as an alternative to a PC. Some of the advantages of Mobile learning are :

- Mobile learning helps learners to improve their literacy and numeracy skills and to recognize their existing abilities
- Mobile learning can be used to encourage both independent and collaborative learning experiences
- Mobile learning helps learners to identify areas where they need assistance and support
- Mobile learning helps to combat resistance to the use of ICT and can help bridge the gap between mobile phone literacy and ICT literacy
- Mobile learning helps to remove some of the formality from the learning experience and engages reluctant learners [1], [2].

## 3. SAFE LIFTING CALCULATOR

The NIOSH Equation is a tool used by occupational health and safety professionals to assess the manual material handling risks associated with lifting and lowering tasks in the workplace. This equation considers job task variables to determine safe lifting practices and guidelines. The well known NIOSH Work Practices Guide for Manual Lifting can assist in determining which lifts are "safe" (that is, which lifts are associated with an acceptable risk) and which lifts are "unsafe" (that is, which lifts are associated with an unacceptable risk) [10]. With the help of the NIOSH *Guide*, employers can inventory lifting tasks assigned to their employees and then implement reasonable steps to control lifting related back injuries. Using the same guidelines, manufacturers can recognize the risk of back injury associated with their products and then design their products to eliminate such risk or properly label their products to warn and instruct about proper methods of lift. The revised equation was developed in 1991 to accommodate asymmetrical lifting and coupling and published in July 1993 [17].

Recommended Weight Limit (RWL) is the principal product of the revised NIOSH lifting equation. The RWL is the weight of the load that nearly all healthy workers could perform in a specific set of task conditions over a substantial period of time (e.g. up to 8 hours) without an increased risk of developing lifting-related low back pain. The revised lifting equation for calculating the RWL is based on a multiplicative model that provides a weighting for each of six task variables. The weightings are expressed as coefficients that serve to decrease the load constant. The load constant represents the maximum recommended load weight to be lifted under ideal conditions. The RWL is defined by the following equation:  $RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$ . Task variables needed to calculate the RWL:

H = Horizontal location of the object relative to the body; V = Vertical location of the object relative to the floor; D = Distance the object is moved vertically; A = Asymmetry angle or twisting requirement; F = Frequency and duration of lifting activity; C = Coupling or quality of the workers grip on the object.

The RWL can be used to guide the redesign of existing manual lifting jobs or to design new manual lifting jobs. For example, if the task variables are fixed, then the maximum weight of the load could be altered so as not to exceed the RWL. If the weight is fixed, then the task variables could be optimized so as not to exceed the RWL.

The lifting index (LI) provides a relative estimate of the level of physical stress associated with a particular lifting task. It is defined by the relationship of the weight of load lifted (L) and the RWL. In equation form this index is  $LI = L/RWL$ . If the magnitude of the LI increases the level of the risk for the worker performing the job would be increased or a greater percentage of the workforce is likely to be at risk for developing lifting-related low back pain.

### 3.1 Online Application

Based on the NIOSH Equation and Snook and Ciriello tables [13], an Excel version of this tool will be presented as a valuable application for online learning. NIOSH Lifting Equation Calculator could be assessed from <http://www.ergoplus.com/healthandsafetyblog/ergonomics/niosh-lifting-equation-single-task/> where "A Step by Step Guide to Using the NIOSH Lifting Equation for Single Tasks", by Mark Middlesworth could be found. Two cases, one with nominal risk, and the other where engineering or ergonomic intervention should be implemented are presented in

Figure 1 and 2 (respectively). Upon entering the necessary information, the calculator suggests if the lifting task is safe or if changes are needed. It is obvious how, by varying the relevant parameters in the equation, the outcome changes.

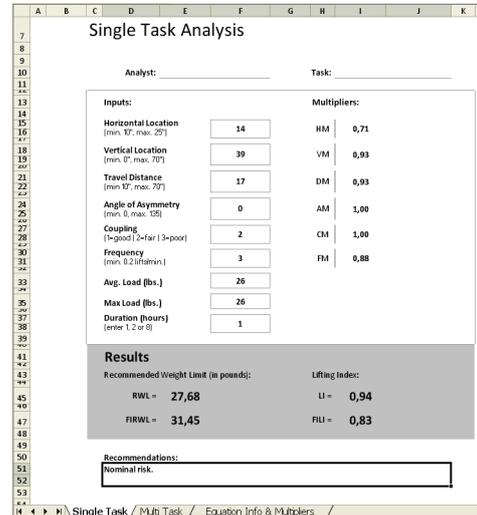


Figure 1. Risk assessment using NIOSH Lifting Equation calculator (case of nominal risk)

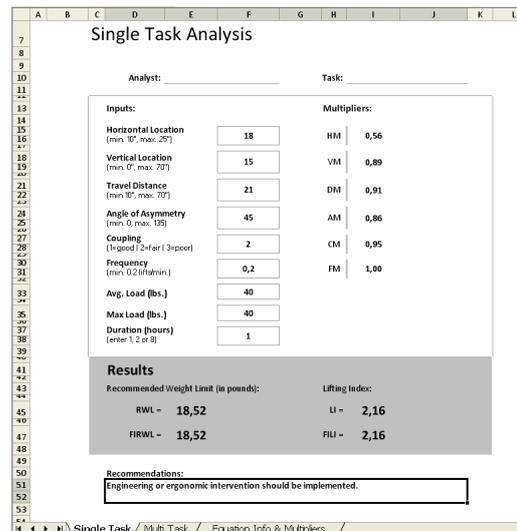


Figure 2. Risk assessment using NIOSH Lifting Equation calculator (case where engineering or ergonomic intervention should be implemented)

### 3.2 Mobile Application

Another, more interesting is mobile application-Oregon OSHA's easy lift app which uses a modified version of the NIOSH lifting equation to give the user a maximum safe weight for various lifting scenarios. By inspection the Google Play App Store, Safe Lifting Calculator was found to be available for unconditional usage. The use of the following steps will assist in determining a safe working weight. Factors based on, starting position, repetition, and duration of the task will be used to calculate the maximum weight that may be lifted safely. The

purpose of this calculator is to identify the lifting limit and ensure that starting weight does not exceed the lifting limit. The first step is to select the position of hands when starting to lift or lower the objects, i.e. above the head, below the knees, close/away from the body etc. Then, the number that corresponds to the times the person lifts per minute and the total number of hours per day spent lifting will be selected.



Figure 3. Example when Weight Lifted (14-17 lbs.) represents moderate risk for injury requires to consider controls to reduce or eliminate risks

The calculator indicate the maximum safe lifting limit we should use (Fig. 3). In the first example the hands position when starting to lift or lower the objects is below the knees, in the middle position, with the frequency of lifting of 2-3 lifts every min for 1-2 hours, the maximum safe lifting limit if the task involves twisting 45 degrees or more will be 14 lbs. or (6.35 kg), while for the job which requires twisting under 45 degrees, the allowed weight will be 17 lbs. (7.71 kg).

Figure 4 shows that when the hands position when starting to lift or lower the objects is at the top of head level up to 3 inches below the shoulder, with the same lifting frequency as in the above example,

the calculator show that the acceptable maximum weight if the task involves twisting 45 degrees or more will be 7 lbs. or (3.18 kg), while for the job which requires twisting under 45 degrees, the allowed weight will be 8 lbs. (3.63 kg).

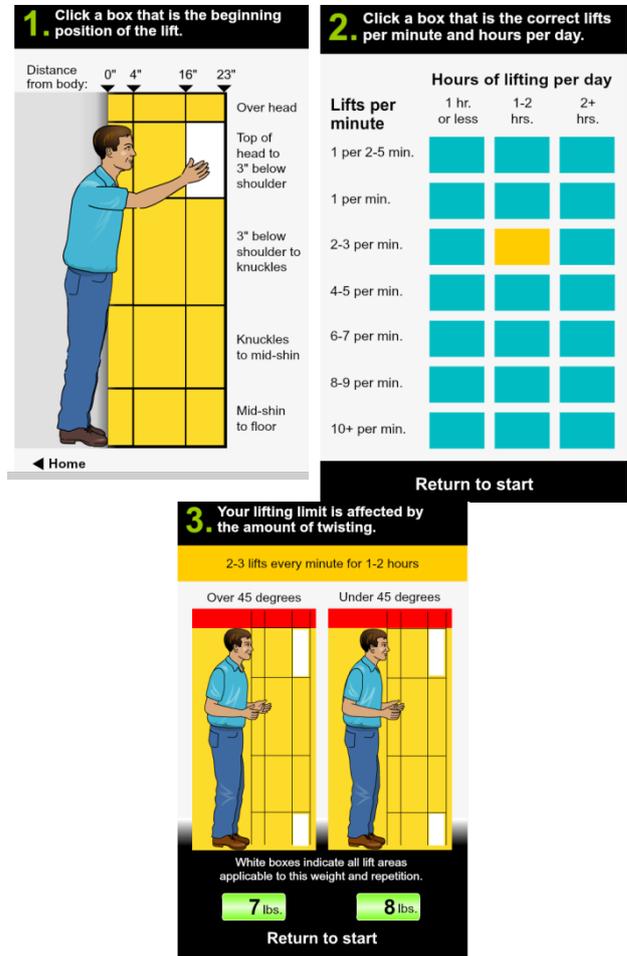


Figure 4. Example when Weight Lifted (7-8 lbs) represents high risk for injury, controls to reduce or eliminate risks required

In the case of the same lifting frequency, the vertical hands position and the distance from the body determines the maximum safe lifting limit, the higher hands position and the distance from the body, leads to decreasing of the maximum object weight. When the lifting frequency remains the same, but the hands position is between waist and shoulder and away from the body, this lift/lower presents high risk for injury and requires controls to reduce or eliminate risks as soon as possible (Fig. 5).

Finally, with increasing lifting frequency of more than 10 lifts every minute within 1 hour, the maximum acceptable weight is very low, if the task involves twisting 45 degrees or more it will be 3 lbs. or (1.36 kg), while for the job which requires twisting under 45 degrees, the allowed weight will be 4 lbs. (1.81 kg) as could be seen from Fig. 6.

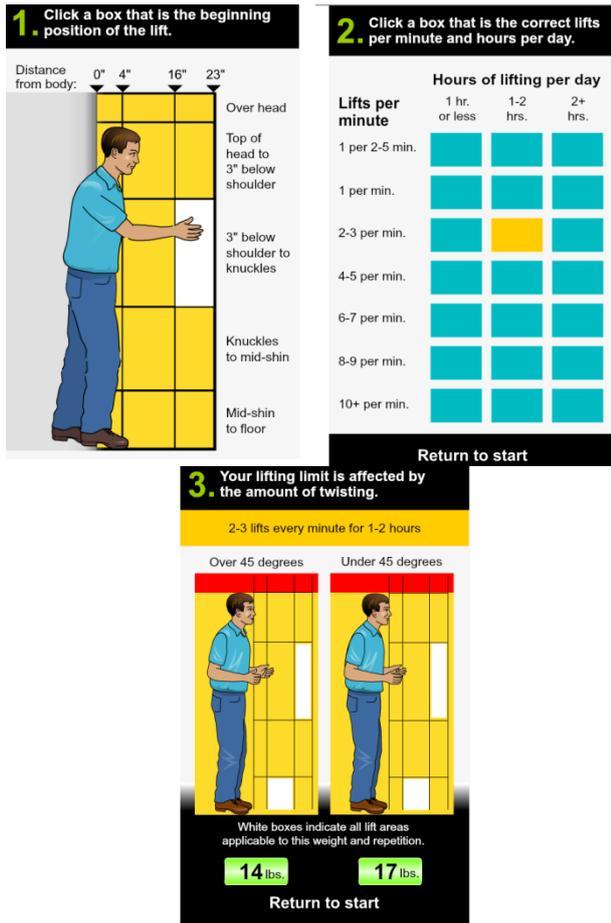


Figure 5. Example when Weight Lifted (14-17 lbs.) represents moderate risk for injury requires to consider controls to reduce or eliminate risks

#### 4. CONCLUSION

The main advantage of this application is that it provides extremely fast, real-time feedback. Managers or workers need the reliable data about risks and stress on the low back, when on the manufacturing floor, when they are in the warehouse, on the assembly line, right beside the conveyor belt, etc., but without taking relatively heavy laptops. Now it can be done using tablets or smartphones. The application determines the risk level for any particular lifting task. It can be used at the job site to evaluate both existing and proposed lifting conditions to determine the Recommended Weight Limit (RWL) for a specific job or task, and could identify those jobs or tasks that might require ergonomic intervention. The platform also gives opportunities for improvement. It shows the relative contribution of each variable - factor and tells about the biggest impact on how safe this lifting task is, so how should, for example, the horizontal reach from one to another point be reduced, in other words, it suggests ergo solution. All the information could be

shared across the company platform and collaborating to minimize risk.

Each of the two presented applications has its benefits, online application provides a comprehensive insight in the different variables of the task, and the manner how their values vary according to the job demands. On the other hand, the mobile application contains fewer details, giving faster feedback, but its' distinctive peculiarity and advantage is mobility, i.e. the possibility to be used on different mobile devices.

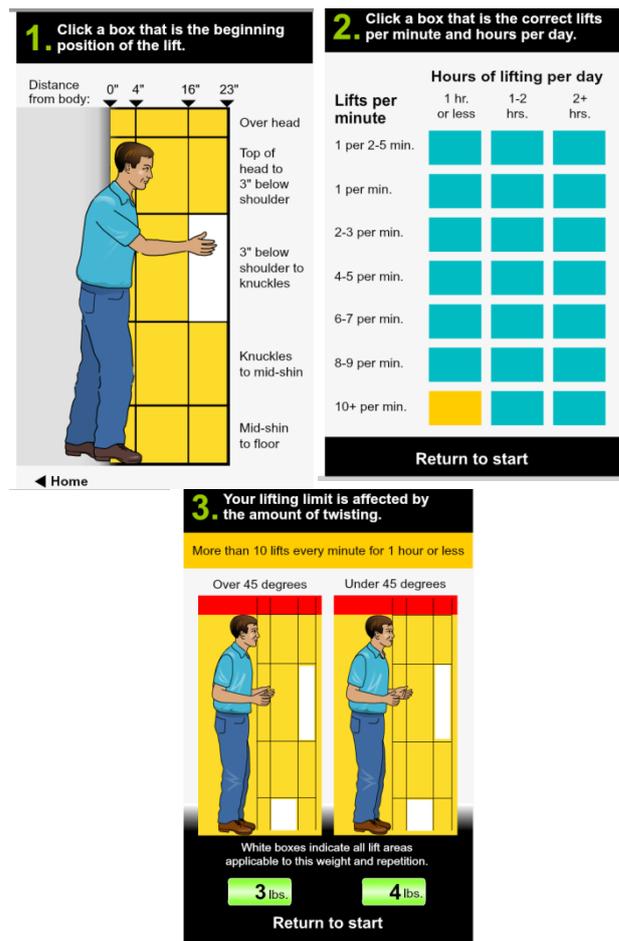


Figure 6. Example when Weight Lifted (3-4 lbs.) represents high risk for injury, controls to reduce or eliminate risks required

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