4th Logistics International Conference
Belgrade, Serbia, 23.-25. May 2019.

Editors

Milorad Vidović
Milorad Kilibarda
Slobodan Zečević
Gordana Radivojević
Momčilo Miljuš

Proceedings of the 4th LOGISTICS INTERNATIONAL CONFERENCE

LOGIC 2019
Belgrade, 23-25 May, 2019

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Publisher: **University of Belgrade, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, Belgrade, Serbia**
http://www.sf.bg.ac.rs

In behalf of publisher: **Prof. Dr. Nebojša Bojović**
Dean of Faculty of Transport and Traffic Engineering

Publishing editor: **Prof. Dr. Marijana Petrović**

Year: **2019**

Conference organizer: **University of Belgrade, Faculty of Transport and Traffic Engineering, Department of Logistics, Belgrade, Serbia**

Supported by: **Ministry of Education, Science and Technological Development of the Republic of Serbia**

Printed by: **PEKOGRAF d.o.o.,Vojni put 258/d, 11080 Zemun, Serbia**

Cover design by: **Dr. Nenad Bjelić**
University of Belgrade, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, Belgrade, Serbia

First edition, no. of copies: **30**

ISBN: **978–86–7395–402–8**

The papers are peer-reviewed by international experts.

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

658.286(082)

LOGISTICS International Conference (4 ; 2019 ; Beograd)
Proceedings of the 4th Logistics International Conference [LOGIC 2019], Belgrade, 23-25 May, 2019 / editors Milorad Vidović ... [et al.]. - Belgrade : University, Faculty of Transport and Traffic Engineering, 2019 (Zemun : Pekograf). - 335 str. : ilustr. ; 24 cm

Tiraž 30. - Bibliografija uz svaki rad.

ISBN 978-86-7395-402-8

а) Логистика -- Зборници

COBISS.SR-ID 277275148

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 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.

Preface to the 4th LOGIC proceedings

Our 4th LOGIC meeting further paves the way for how we should perceive logistics. To pave the way this year helped us 87 authors presenting 37 papers, together with 18 presentations in workshops. The fourth conference raised interest of people from 16 countries, while speakers and discussants came from 11 countries, giving to the conference pure international profile. In a different conference sessions, through two days, more than 250 people have taken active participation. Beginning with the idea of being meeting place and forum for exchanging ideas, still keeping those values, LOGIC conference gradually grows profiling itself as a place where ideas are not only discussed but also generated and created.
Now, 4th LOGIC proceedings book is here, giving us opportunity to have insight into the participants ideas and their thoughts on logistics.
This volume brings together all accepted research papers presented at the conference. As the logistics itself, this book covers wide specter of different topics, from the modeling and planning to innovative methods, latest technologies and practice. If one tries to find the common line, maybe it may be found in authors effort to respond to different challenges arising from constantly changing environment. Although the book primarily addresses problems related to logistics, and therefore potentially beneficial for students and professionals interested in logistics, we do hope that because of interdisciplinary nature of logistics, it would be also helpful for wider auditorium.
To make this conference, and keep it quality and continuity, 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 "platinum" sponsors, companies Milšped and Delhaize Serbia, together with "gold" supporters: Gebruder Weiss, Cargo Partner, Nelt, DTS, Transfera, Geodis and Dunav; and "silver" supporters: NTS, Cargo Market, RALU logistika, Infora, Fercam, LogIT, Standard logistics, Špica, BAS, Zlatiborac, Coca-Cola HBC, Cube Team, Nestle, Sarantis,

Srbijatransport and Logistika i transport. More visibility provided our media supporter Pluton logistics.
To all of them we would like to express our sincere thanks and appreciation!
To continue the tradition, we warmly invite you to meet again on the 5th LOGIC conference to be held in 2021.

Belgrade, June 2019 Program committee chair

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Part I

OPTIMIZATION AND MODELLING IN LOGISTICS AND TRANSPORTATION

FORECASTING FUTURE TRENDS IN FREIGHT TRANSPORT IN SLOVENIA UNTIL THE YEAR 2030

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Abstract: *Slovenia regarding the freight traffic belongs at the very top of the EU, while every sixth truck is excessively overloaded. The main aim of the present study is to accurately forecast future freight traffic on the highways until the year 2030. For this purpose, the adequate Box-Jenkins time series model has been identified. In order to obtain the best possible structure and parameters of a final model, a unique heuristic modeling framework containing an entire composition of different rigorous statistical criteria has been applied. For making predictions of future freight transport, a Monte Carlo scenario-playing framework has been conducted. The results show that an interval forecast (16458, 20671) million Tkm with a 95% likelihood is expected at the beginning of 2030. Regarding the practical point of view, this study has contributed to a decision-making process while studying different planning approaches about adequate fees' systems for trucks on the highways.*

Keywords: *Transport Planning; Forecasting Models; Monte Carlo Procedure; Road Freight Transport in Slovenia.*

1. INTRODUCTION

In terms of the share of international freight transport, Slovenia belongs to the very top of the members of the European Union; in addition, every sixth truck is overloaded. It is also estimated that the freight traffic will considerably increase over the next 15 years, with diverse projections that are quite different from one another. The main aim of this study is to try to predict, in the most professional and credible way, the increase in freight traffic by 2030.

According to the official facts, foreign trucks represent more than 90 percent of total freight traffic in Slovenia, while only Lithuania has a higher share. In many countries, for example in Italy and Germany, the ratio between foreign and domestic trucks is just the

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opposite (Ocepek, 2013). In the case of Austria, a drop in transit traffic is evident, especially due to strict environmental policy. As a result of this fact, the bulk of transit freight transport has moved to the neighboring countries, particularly to Slovenia. In the countries of Central Europe, such as Slovakia, the Czech Republic, Hungary and Slovenia, there has been a significant increase in international freight transit traffic since 2004, when these countries joined the European Union (Ocepek, 2013).

The reasons for such an increase in transit freight transport are, for example, the enlargement of the EU and the subsequent Schengen area, as well as the significance of the strategical position of Slovenia being located at the crossroads of the 10th and 5th European transport corridor. In addition, some other reasons also contribute to an increase in foreign transit, such as, for example, price and low tolls, which is the reason why freight flows prefer to be redirected across Slovenia, rather than going on a shorter path (Ocepek, 2013). Latest state shows that highway driving is changing to endless overtaking of trucks on weekdays. The most heavily burdened sections of Slovenian highways transports are approaching to a load of seven thousand trucks weighing more than seven tons a day, so one every 12 seconds.

There are several ways to solve problems related to overloaded transit freight transport. One way is to gradually move freight from the roads to a railway network. Unfortunately, this is not possible at the current moment for Slovenia. The reasons are enormous costs, associated with a reconstruction of the obsolete and slow rail network. Also, other related investments, in this case, would be too costly and thus are unacceptable. The rising of tolls is also not a solution, mostly due to bilateral and multilateral political reasons on the relation (Slovenia – the EU, Slovenia – other EU countries). Thus, the only acceptable way has been the construction of a new and efficient toll system that can usually significantly decrease the existing traffic flows.

As a response to problems mentioned above, on the April 1st this year, a new free-flow electronic tolling system (ETS) has been initiated on Slovenian highways for heavy goods vehicles. While a couple of studies related to choosing of most appropriate technology for ETS have been carried out, a DSRC (Dedicated Short Range Communication) technology was finally selected (Kroflič, 2017; Miller et al., 2001).

As it is usual in wider planning of important transport projects, the planning of possible strategies must also take into account the most possible accurate long-term forecasting of future trends in freight transport. This is particularly important in the case of planning any of strategic future transport policies and strategies on the state level including a design of an appropriate tolling system on highways, where most freight traffic takes place, especially transit.

Our forecasting study was one of the key studies carried out during the process of choosing of most appropriate technology for ETS. Namely, the information about future trends of freight road transport on Slovenian highways was one of the key parameters during the decision-making process (DMP) regarding choosing the most suitable type of ETS. For the purpose of the study, the ARIMA model from the family of the Box-Jenkins time series models (Box et al., 2015) was used and integrated into the Monte Carlo scenario playing (MCSP) procedure for testing possible future scenarios. The entire ARIMA-MCSP framework represents a unique forecasting mechanism, with a composition of different rigorous criteria for selecting the most appropriate forecasting model. We believe that the paper might have included several contributions from the methodological and practical point of view, such as: a) the study presented here was one of the key studies during the DMP process of choosing the ETS system; b) to the best of our knowledge, practically none of the similar studies can be found in the existing literature; c) The unique ARIMA-MCSP framework was conducted for the case of traffic flow forecasting.

2. THE LITERATURE REVIEW

In general, we can classify traffic flow forecasting into two categories: a) short-term forecasting (STF); and b) long-term forecasting (LTF). The STF forecasting is particularly important for advanced traffic management and for information systems that belong to the intelligent transportation systems (ITS), mostly in the urban metropolitan areas (Bing et al., 2018). Here, the observation period and the forecasting horizon are typically considered in minutes' or hours' intervals. The forecasting methods in this respect can be roughly divided into parametric methods (PM) and nonparametric methods (NPM). The PM methods mostly include ARIMA and other Box-Jenkins time series models (Box et al., 2015), Kalman filtering-based models (Guo et al., 2014), and other parametric regression models. To overcome some limitations of PM models (e.g., normality of model's residual), many studies have also conducted NPM methods, such as: nonparametric regression models, neural networks' models, spectral analysis's models, support vector machines' models, and many more (Bing et al., 2018; Zhang, 2014).

Conversely to the STF models, there could not be detected many studies that would deal with a long-term traffic flow forecasting, particularly the ones that are also addressing the goods transport on the state level. In a study (Ishida and Okamoto, 2011), billions vehicle-km/year has been predicted regarding freight transport in Japan within a time interval [1980, 2030] by using log-linear regression models. The work of authors (Jha et al., 2016) has conducted the prediction of the total vehicular population in India by using different time intervals (up to the year 2021) and various ARIMA models. There have been also several other similar studies detected on the country (state, big city) level, such as for: 1) Australia; 2) India; 3) Illinois US; 4) Turkey; 5) Poland; 6) New Zealand; 7) North Carolina US; 8) Beijing, China; 9) Paris, France; 10) Spain; and 11) Pakistan.

Only some of these studies are dedicated exclusively to freight transport on the country (state) level. Their common denominator is that they possess a wider prediction time interval, which is monitored in terms of days, weeks, months or years ahead. The models for LTF forecasting vary from simple models (e.g., trend line models, linear-growth or log-linear models, exponential smoothing models), more complex classical models (e.g., Box Jenkins models, econometric models, ARMA-GARCH models, Dynamic Factor models, etc.), all over to advanced modern models (e.g., neural and fuzzy-neural models, agent-based models, models based on regression with support vectors, etc.). There are also a number of alternative models specially built for specific cases of traffic flow forecasting.

Details about these studies and applied models can be found in the literature (Chase et al., 2013; Choudhary et al., 2014; Chow et al., 2010; Chrobok, 2005; Dhingra et al., 1993; Dogan et al., 2018; Dorosiewicz, 2015; Gomez and Vassallo, 2015; IDFC, 2016; Jha et al., 2016; Jha et al., 2013; Kennedy and Wallis, 2007; Kulelpak and Sennaroglu, 2009; Li and Hensher, 2009; Matas and González-Savignat, 2009; Raikwar et al., 2017; Sabry et al., 2007; Slattery et al., 2004; Stone et al., 2006; Su et al., 2016; Toque et al., 2018; Tsekeris, 2011; Yu et al., 2017).

3. THE CONCEPTUAL FRAMEWORK OF A MODELING DESIGN

3.1 The characteristics of the data

Regarding historical data for the transport volume, it worth to mention that traffic flows (in million-ton kilometers – mio Tkm) have been monitored in Slovenia already since the year 1954, with a higher level of precision since the year 1992 (Zanne, 2013). Concerning the systematic (automated) measurement of freight traffic, the latter has been monitored by the Directorate for Roads of the Republic of Slovenia since 2002 with automatic counters (Zanne, 2013). Trucks' loads were measured in 2003 in 30 locations and in 2011 at 39 locations.

3.2 The applied forecasting model and relations with our previous work

While a procedure for searching the best ARIMA model's structure and parameters was carried out, a unique heuristic-based approach for model selection was designed. The latter has incorporated a whole spectrum of different rigorous criteria, from the statistical-based, residual-based, all over to information-based criteria. The main working mechanism of this approach was previously introduced and applied in several other studies from the field of Maritime logistics (Dragan et al., 2017a; Intihar et al., 2015, 2017). For making predictions of long-term future freight transport in Slovenia, an MCSP framework was applied combined with a previously identified ARIMA model (Dragan, 2016). The main concept of combining different models with the MCSP concept was in-depth explained in a couple of other similar research studies, e.g., works (Dragan et al., 2017b; Ivanuša et al., 2018).

3.3 The conceptual framework

Figure 1 shows the conceptual framework of an entire modeling design. Firstly, the 100 quarterly data from 1990 to 2014 was collected (Block A). These data were assigned to the observed time series variable denoted by $z(t)\,, t = 1990Q_1,...,2014Q_4$. The identification of the best ARIMA model has followed in the next step (Block B). The best model was found among an entire family of the model candidates with different models' parameters, structures and orders, for which an estimation interval (EI) $t_e \in \{1990Q_1,...,T_u = 2007Q_2\}$ was taken into account. For this purpose, the unique heuristic algorithm for model selection (firstly introduced in (Intihar et al., 2015)) represented in Block C was applied in a slightly adjusted form for the case of traffic flow forecasting (c.f. figure 2 (Intihar et al., 2017)). This heuristic also provided an appropriate validation of the best model (Block D) on the test interval (TI) $t_t \in \{T_u + Q,...,2014Q_4\}$. The interested reader can find the details of the working mechanism of this algorithm in our previous work (e.g., (Intihar et al., 2017)). The model with its output denoted by $\hat{z}(t)\,, t \in t_p$ was afterwards injected into the MC algorithm (Block E), which has produced several hundred ($i = 1,...,M_S$) possible future scenarios $\hat{z}(t,i)\,, i = 1,...,M_S, t \in t_p$ on the prediction interval (PI) $t_p \in \{2015Q_1,...,T_P = 2030Q_1\}$ (Block F). As a final step, an averaging of future scenarios (Block G) was carried out across entire prediction interval with a purpose of obtaining of average (mean) values of the interval forecasts $\bar{\hat{z}}(t,i) \pm 2 \cdot STD(\hat{z}(t,i)), i = 1,...,M_S, t \in t_p$, where $\bar{\hat{z}}(t,i)$ are the averaged future point forecasts. Moreover, the normality test was also conducted for future scenarios $i = 1,...,M_S$ in the final time point $T_P = 2030Q_1$. As it turned out, the future scenarios have been approximately normally distributed here, which means:

$$\hat{z}(2030,i) \approx N\left(\bar{\hat{z}}(2030,i), STD\left[\hat{z}(2030,i)\right]\right), i = 1,...,M_S, t = 2030$$
$$P\left[\bar{\hat{z}}(2030,i) - 2\cdot STD\left[\hat{z}(2030,i)\right] \le \hat{z}(2030,i) \le \bar{\hat{z}}(2030,i) + 2\cdot STD\left[\hat{z}(2030,i)\right]\right] \approx 95\% \tag{1}$$

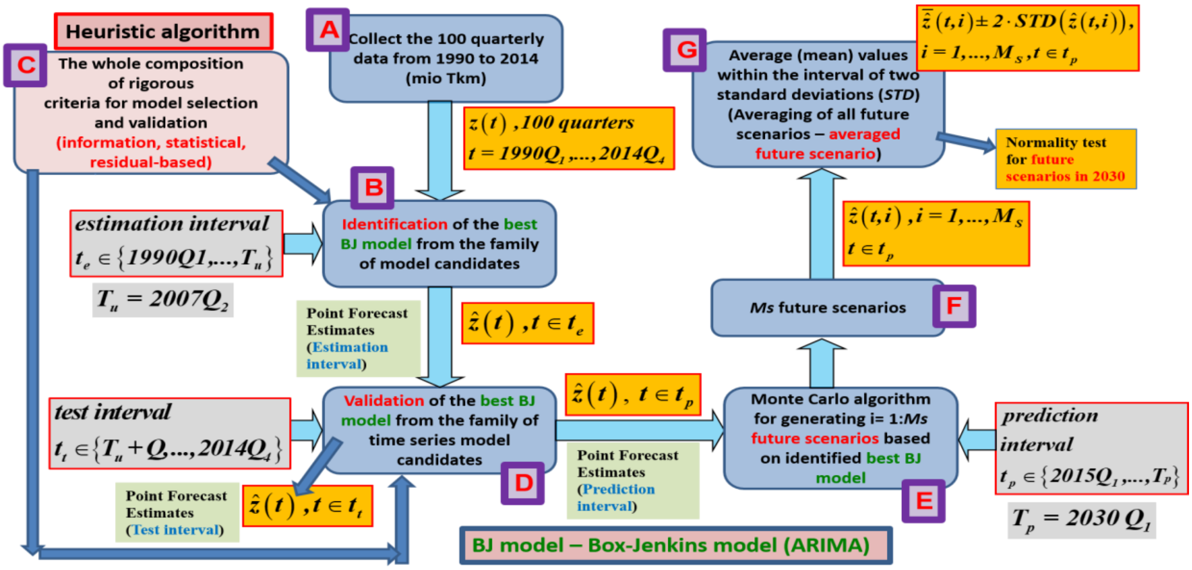

Figure 1. The conceptual framework of an entire modeling design.

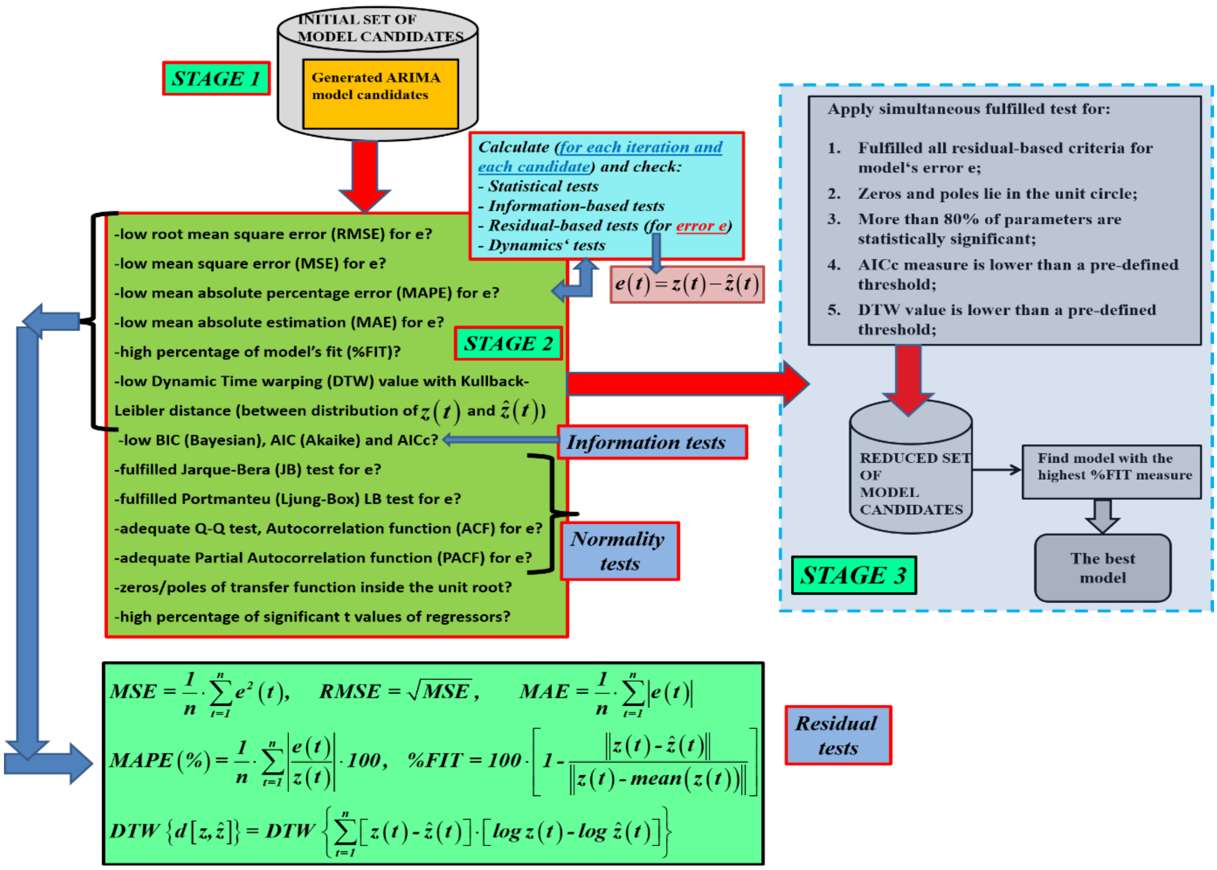

Figure 2. The heuristic algorithm for model selection to find the best ARIMA model.

4. THE ARIMA MODELS

In general, the structure of the ARMA models family can be represented by the following expression (Box et al., 2015; Ljung, 1998, 2000):

$$z(t)+\sum_{i=1}^{n_a} a_i \cdot z(t-i)=\varepsilon_z(t)+\sum_{k=1}^{n_c} c_k \cdot \varepsilon_z(t-k) \tag{2}$$

where the AR part's order n_a and MA part's order n_c refer to the oldest delay of output $z(t)$ and the oldest delay of random noise $\varepsilon_z(t)$, respectively. The noise is supposed to have the properties of the white noise. The equation (2) can also be rewritten in the more compact form of a transfer function (TF) equation, if the backshift operator q^{-1} is conducted (Ljung, 1998, 2000):

$$\begin{aligned} &A(q)\cdot z(t)=C(q)\cdot \varepsilon_z(t),\ where: \\ &A(q)=1+a_1\cdot q^{-1}+\ldots+a_{n_a}\cdot q^{-n_a} \\ &C(q)=1+c_1\cdot q^{-1}+\ldots+c_{n_c}\cdot q^{-n_c} \end{aligned} \tag{3}$$

The ARIMA transfer function model has a similar structure as the model in expression (3), but the non-stationary output's time series $z(t)$ must be substituted with its differentiated equivalent. Usually the first order's differentiation can achieve the stationarity, i.e.: $\Delta z(t)=z(t)-z(t-1)=\left(1-q^{-1}\right)\cdot z(t)$. This way, the TF in (3) takes the form:

$$\begin{aligned} &A(q)\cdot \Delta z(t)=C(q)\cdot \varepsilon_z(t) \\ &A(q)\cdot\left(1-q^{-1}\right)\cdot z(t)=C(q)\cdot \varepsilon_z(t) \end{aligned} \tag{4}$$

5. THE NUMERICAL RESULTS

5.1 The data for road freight transport

Figure 3 shows the 100 quarterly historical time series data for Slovenian freight transport, measured over the period from 1990 up to 2014. From Figure 3 it can be noticed that freight transport significantly increased after the year 2004 when Slovenia entered into the EU. During the time of economic crisis, an oscillatory behavior can be noticed with a significant drop that has resulted in a local minimum reached in the third quarter of the year 2009. Later, the time series was stabilized with a slight drift that was present until the year 2014.

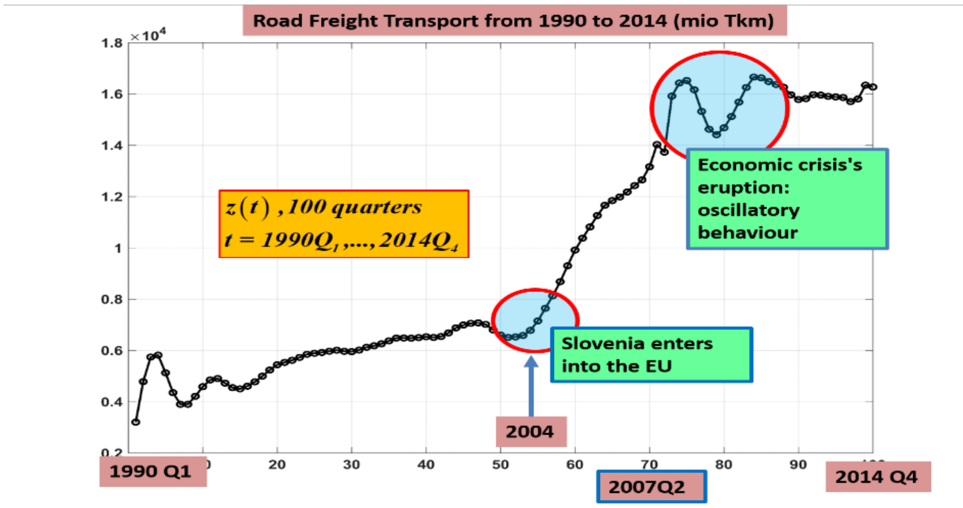

Figure 3. The quarterly data for road freight transport in Slovenia from 1990 to 2014.

5.2 The estimation of the best ARIMA model

All calculations were conducted in Matlab with its extensions: The Statistics Toolbox, Econometrics Toolbox, and The System Identification Toolbox. The obtained ARIMA(2,1,1) model has the following estimated transfer function:

$$\begin{aligned} &A(q)\cdot\Delta z(t) = A(q)\cdot\left[z(t)-z(t-1)\right] = C(q)\cdot\varepsilon_z(t) \\ &A(q) \;=\; 1 \underbrace{-1.328}_{(t(a_1)=-12.883)} \cdot q^{-1} \underbrace{+0.6303}_{(t(a_2)=7.3743)} \cdot q^{-2} \\ &C(q) \;=\; 1 \underbrace{+0.3801}_{(t(c_1)=2.4961)} \cdot q^{-1}, \quad \left|t(a_1)\right|,\left|t(a_2)\right|,\left|t(c_1)\right| > t_{krit} = 1.9966 \end{aligned} \tag{5}$$

The values in parenthesis represent the t-values of the obtained parameters, which are all statistically significant ($\left|t(a_1)\right|,\left|t(a_2)\right|,\left|t(c_1)\right| > t_{krit} = 1.9966$). For the estimation of parameters, the first 70 time samples were applied, while in the testing of the predictive power of the model, the last 30 time samples were used.

5.3. Model validation

The model (5) has passed all the rigorous tests presented in figure 2. The diagnostic checking has given us the following important results (see equations in figure 2):

$$\begin{aligned} &AIC = 637.3656, \quad RMSE = 92.1291, \quad MAE = 65.3397 \\ &MAPE(\%) = 1.9122, \quad \%FIT = 82.1165, \quad DTW\{d[z,\hat{z}]\} = 78.2293 \end{aligned} \tag{6}$$

Since the MAPE is quite low, while the %FIT implies the fairly well fit of a model to the real data, we can conclude that the model might be efficiently used for predictions.

5.4. The prediction results

Figure 4 shows the model's output $\hat{z}(t)$ and fit to the real data $z(t)$ on the estimation interval: $t_e \in \{1990Q_1,...,T_u = 2007Q_2\}$, and on the test interval: $t_t \in \{T_u + Q,...,2014Q_4\}$. As can be noticed from figure 4, in general, the model fits the real data quite well on the estimation interval. On the test interval, after the initial oscillatory overshoot, the model gradually manages to capture the real data with a reasonably well fit.

Figure 4 also shows several hundred $(\boldsymbol{i = 1,...,M_S})$ generated future scenarios $\boldsymbol{\hat{z}(t,i)\ ,i = 1,...,M_S, t \in t_p}$ on the prediction interval $\boldsymbol{t_p \in \{2015Q_1,...,T_P = 2030Q_1\}}$. Moreover, Block A points to the average (mean) values of the interval forecasts $\boldsymbol{\bar{\hat{z}}(t,i) \pm 2 \cdot STD(\hat{z}(t,i)), i = 1,...,M_S, t \in t_p}$, where $\boldsymbol{\bar{\hat{z}}(t,i)}$ are the averaged future point forecasts. As it turned out, the normality tests (Jarque Bera test, Ljung-Box test, etc.) has confirmed that the future scenarios $\boldsymbol{\hat{z}(2030,i), i = 1,..., M_S}$ are approximately normally distributed in final time point $\boldsymbol{T_P = 2030Q_1}$. Consequently, it turns out that the following equations occur after the end of the MCSP procedure (see also equation (1) and Blocks from B to E in figure 4):

$$\begin{aligned} &\hat{z}(2030,i) \approx N(18565,1053), i = 1,...,M_S, t = 2030 \\ &P(16458 \le \hat{z}(2030,i) \le 20671) \approx 95\% \end{aligned} \tag{7}$$

Considering the fact that normality of $\hat{z}(2030,i)$ has been achieved, it can be concluded that there is a likelihood with a 95% probability of confidence in the result that the actual value of freight traffic at the beginning of 2030 will reach a certain value at the interval $\mathbf{(16458, 20671)}$ **million Tkm**. Furthermore, the most probable results can be expected around a value of **18565 million Tkm** of road freight transport that will be most likely achieved in the year 2030.

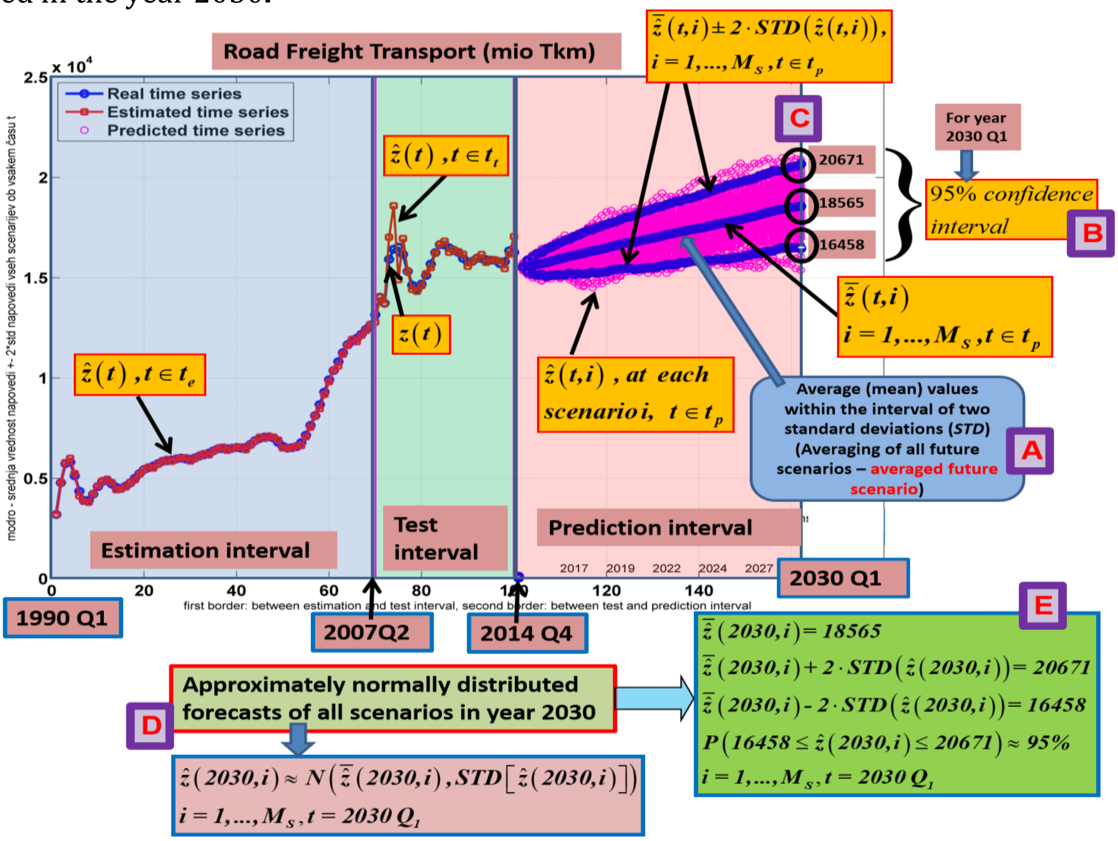

Figure 4. The prediction results for the road freight transport in Slovenia.

6. CONCLUSION

The combined Monte Carlo Scenario Playing framework with integrated ARIMA model (2,1,2) has been introduced in this paper. The main purpose was to design a forecasting mechanism that would fairly accurately predict the future trends in freight transport in Slovenia until the year 2030. The study presented here was one of the crucial studies carried out during the process of choosing the most suitable technology for a newly designed electronic tolling system. In the future work, it is planned to methodologically upgrade a forecaster by the inclusion of additional modeling of possible seasonal, cyclic, intervention, and other effects. Moreover, it is also planned to enrich a model with influential economic exogenous indicators (such as GDP, import, export, etc.), which also presumably significantly impact on the dynamics of road freight transport.

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MODELING ALLOCATION OF HIVES

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Abstract: *The contribution of insect pollinators to the economic output is obvious. Several alternative bee species have been identified to be capable of replacing or at least supplementing decreasing number of honey bees. Our research aim to deal with location of nesting aids for solitary bees in orchards using mathematical programming models for determining the optimal location of nesting aids and thus can be used to optimize the management of solitary bees.*

Keywords*: hive location, pollination management, crop pollination, Osmia cornuta.*

1. INTRODUCTION

Insect pollination is important service for agriculture crops, many field crops require an operating pollination system, influencing the productivity of approximately 75% crop species (Klein et al., 2006) and 80% of all flowering plant species rely on animal pollinators (Kluser & Peduzzi, 2007). The area of insect pollination crop has grown substantially in recent decades, resulting in greater demand for pollination services (Aizen, Garibaldi, Cunningham, & Klein, 2008). A worldwide decline of pollinators abundance and diversity is recorded over the last years and fueled the debate of sustainability of the current intensive farming (Hole et al., 2005). Insufficient pollination is a common case of a poor yield for example of pears (Soltész, 1996), (Monzón, Bosch, & Retana, 2004).

Although honey bees (*Apis mellifera*) can be used as a pollinators in in large commercial orchards to improve productivity (Delaplane, Mayer, & Mayer, 2000). A number of other insects, notably solitary bees (e.g. *Osmia spp. Andrrena spp.*) and bumblebees (*Bombus spp.*) have been studied as alternative pollinators and demonstrated to be effective pollinators of for example apple, pear, cherry, pear orchards and in some cases more effective than honeybees (Martins, Gonzalez, & Lechowicz, 2015). Possible advantages of alternative pollinators are temperature when pollinators are active, preference for foraging and stigma contact by floral visitor.

Temperature and relative humidity do not effect *Osmia cornuta* presence in the orchard (Vicens & Bosch, 2000b) (B. Maccagnani, Ladurner, Tesoriero, Sgolastra, & Burgio, 2003).

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Commercial yields in Osmia pollinated orchards are achieved even in yields with poor weather during bloom (Bosch & Kemp, 1999), (Bosch & Kemp, 2001).

The promising pollinator species should preference for foraging on flowers of the target crop (Márquez, Bosch, & Vicens, 1994). *Osmia cornuta* bees do not look for other food sources in case of pollen decline in pear orchard in contrast with honeybees (Bettina Maccagnani, Burgio, Stanisavljevic, & Maini, 2007). Also pollination influence numbers of seeds and seed sets is important factor in pear commercialization. Parthenocarpic fruits are often smaller than seeded ones, and size is important factor in terms of customer preference. Pears with high numbers of seeds tend to be larger, and have better shape and flavor (Sedgley & Griffin, 2013). High rates of stigma contact by floral visitor are strongly related to the pollinator's behavior on flower. It is well known that honey bees behavior results in low rates of stigma contact, whereas pollen collectors (e.g. *Osmia*) are much more efficient pollinators of the crops (Free, 1993), (Bosch & Blas, 1994), (Vicens & Bosch, 2000a). Rates of stigma contact are sometimes also related to body size of the pollinator relative to the size of the crop flower. Also in orchards with non- *Apis* bees, the foraging behavior of honey bees changed and the pollination effectiveness of the single bee visit was greater than in orchard where non *Apis* bees where absent. The change translated to a greater proportion of fruit sets in these orchards (Brittain, Williams, Kremen, & Klein, 2013).

The contribution of insect pollinators to the economic output is obvious. Several alternative bee species have been identified to be capable of replacing or at least supplementing decreasing number of honey bees (Kremen, Williams, & Thorp, 2002), (Rader et al., 2009). Literature review how to establish and manage bee species as a crop pollinators can be found for example (Bosch & Kemp, 2002), (Gruber, Eckel, Everaars, & Dormann, 2011). Our research aim to deal with location of nesting aids for solitary bees in orchards using mathematical programming models for determining the optimal location of nesting aids and thus be used to optimize the management of solitary bees in orchards. The current practice with honey bees can be described as follows, beehives are kept together on trailer on the edge of the field or orchard where the plants to pollinate are. This location is convenient for the beekeeper, but some distant parts of the orchard can be left not covered, not pollinated because bees need to fly longer distances or will forage on another crop that is closer. In the case of solitary bees, the problem can become more obvious because solitary bees can fly smaller distance compared to honey bees. In the next part of the paper mathematical programming model for determining the optimal location of nesting aids is proposed.

2. MATHEMATICAL PROGRAMMING MODELS FOR DETERMINING THE OPTIMAL LOCATION OF NESTING AIDS

Suppose, the trees that need to be pollinate are randomly located and distances between threes are known. Assume that the nesting aids, hives can be located under the any tree and total number of nesting aids is given. The aim is to pollinate all the trees at a minimum total distance flown by the insect. The basic problem is known as *P*-median problem (ReVelle & Swain, 1970). In our research, we modified this model to the problem of minimal total distance needed to be flown in the case when the total number of nesting aids is given. The constraint for maximum distance the bee can fly is also introduced.

The problem can be formulated as binary programming problem with variables $y_{ij} \in \{0,1\}, x_i \in \{0,1\}, \ i, j = 1, 2, \ldots n$, where n represents the number of the trees in the orchard. The variable $y_{ij} \in \{0,1\}, \ i, j = 1, 2, \ldots n$ represent the event of pollination. The value is equal to 1 if the *j*-th tree is pollinated by bees from *i*-th hive or nesting aid, otherwise the value is equal to 0. The model also deals with binary variable $x_i \in \{0,1\}, \ i = 1, 2, \ldots n$ that represents location of the hive. The value is equal to 1 if the hive, nesting aid is operated under the *i*-th tree, otherwise the value is equal to 0.

The objective deals with parameters $d_{ij}, i, j = 1, 2, \ldots n$ that represent minimal distances between all trees in the orchard. Aims is to pollinate all the trees and the objective function of the problem can be formulated:

$$f(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} y_{ij} \rightarrow \min \tag{1}$$

The first group of conditions represents the need to pollinate all the trees from *i*-th location of the hive.

$$\sum_{i=1}^{n} y_{ij} = 1, \ j = 1, 2, \ldots n \tag{2}$$

Second group models the maximum distance the bee can fly.

$$\sum_{i=1}^{n} d_{ij} y_{ij} \leq K, \ \ j = 1, 2, \ldots n \tag{3}$$

The conditions that represent the need to operate the hive at *i*-th location, belong to the second group of conditions.

$$y_{ij} - x_i \leq 0, \quad i, j = 1, 2, \ldots n \tag{4}$$

It is evident that the number of hives must be restricted:

$$\sum_{i=1}^{n} x_i = p \tag{5}$$

The formulation of the model:

$$\begin{aligned}
& f(\mathbf{x}, \mathbf{y}) = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} y_{ij} \rightarrow \min \\
& \sum_{i=1}^{n} y_{ij} = 1, \ \ j = 1, 2, \ldots n \\
& \sum_{i=1}^{n} d_{ij} y_{ij} \leq K, \ \ j = 1, 2, \ldots n \\
& y_{ij} - x_i \leq 0, \ \ i, j = 1, 2, \ldots n \\
& \sum_{i=1}^{n} x_i = p \\
& x_i, y_{ij} \in \{0,1\}, \ \ i, j = 1, 2, \ldots n
\end{aligned} \tag{6}$$

Where

p – represents number of hives,

d_{ij} – represents shortest distance from *i*-th hive to *j*-th tree or from *i*-th tree to *j*-th tree. It is assumed that possible location of the hives can is under the any tree.

K – represents maximum distance the bee can fly.

Below can be seen the source code for the GAMS program to solve the total minimal distance tasks at a specified number of hives:

```
Sets i /1*n/
alias (i,j);
Scalar p /p/
K /K/;
Table d(i,j);
Variables f;
Binary variable y;
Binary variable x;
Equations uf
first(j)
second(i,j)
third
fourth;
uf.. f=e=sum((i,j),d(i,j)*y(i,j));
first (j).. sum(i,y(i,j))=e=1;
second (j) sum(i,d(i,j)*y(i,j)); )=l=K;
third (i,j).. y(i,j)-x(i)=l=0;
fourth sum(i,x(i))=e=p;
Model totaldistance /all/;
solve totaldistance using mip minimizing f;
```

The illustrative results are demonstrated on Figure 1. The blue dots represent the optimal location of nesting aids in the orchard that is represented by trees that need to be pollinated depicted by red circles.

3. CONCLUSION

The paper presents the model that aims to locate nesting aids for solitary bees in the orchard in order to pollinate all the trees at a minimum total distance flown by the insect. The problem is NP-hard problem. Small instances can be solved by contemporary computation tools. In cases with more trees problem becomes computationally demanding. In the future, we would like to use evolutionary tools to deal with this problem.

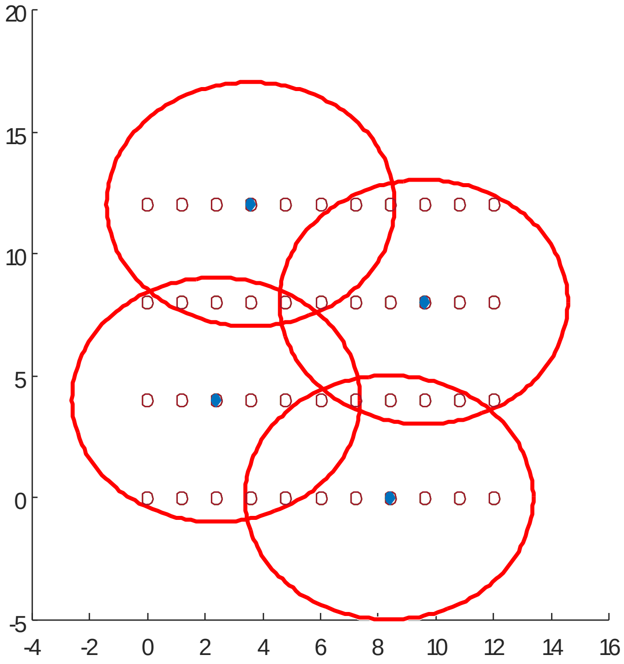

Figure 1. Optimal solution for illustrative example with 44 trees that need to be pollinated

ACKNOWLEDGMENT

This paper is supported by the Slovak research and development agency, grant no. SK-SRB-18-0009 "Optimizing of Logistics and Transportation Processes Based on the Use of Battery Operated Vehicles and ICT Solutions" and VEGA No. 1/0351/17 Application of Selected Models of Game Theory to Solve some Economic Problems of Slovakia.

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BENEFITS FROM COOPERATION BEHAVIOUR IN VEHICLE ROUTING PROBLEM

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Abstract: *In transport systems, there are usually more distribution companies that must serve their customers. Obviously, if companies could cooperate with each other this kind of cooperation can lead to some additional benefits for them. In this paper, we focus on the situation where we anticipate the existence of multiple companies. Each of these companies owns one central depot whereby their customers are served by different types of vehicles. In the case of non-cooperation behavior, each of the companies act independently. However, if we allow the coalition formation between the companies and consider joint customer service, there may be a reduction in the shipping costs resulting from a better customer allocation to the depot. Other benefits may accrue from the simultaneous use of the depots which means that the vehicle can be repeatedly reloaded at another depot (not the starting one). In this paper, we will introduce the new mathematical models to describe these situation. We will also focus on the possible ways of the redistribution these benefits in terms of Game Theory.*

Keywords*: Cooperative Game Theory, Game Theory, Vehicle Routing Problem, redistribution*

1. INTRODUCTION

This article is dedicated to solve the Vehicle Routing Problem following the Game Theory in terms of cooperative behavior of subjects. We will consider a transport system, whose elements can be characterized as follows: a set of and subjects that realizing customer´s service. Each of this subject (logistic company) owns a depot from which it serves its own set of customers. We consider that the initial customer allocation to the logistic company are known. Each customer requires the delivery of a predetermined quantity of goods. The customer´s service is realized by a vehicle that starts and ends its route in its relevant depot, whereby the type of the vehicle can be different for each logistic company (in terms

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of capacity). We also assume that each point of customer´s service is included in the route of vehicle exactly once, delivery of goods is realized at whole and the capacity of individual depot is not limited. The basic assumption is to achieve the lowest possible transport cost in customer´s service (in the simplest case we minimize the distance between the customers and depots). Concluding on this, it could be modeled as an appropriate Vehicle Routing Problem. Cooperation in Vehicle Routing Problem was solved by many authors. For example, Lin (2008) studied cooperative vehicle routing problem with pickup and delivery time windows ad showed that multiple use of vehicles can reduce costs. Lozano (2013) introduced a mathematical model to quantify the benefits from merging the transport requirements of different companies. For example, McCain (2008) focused on analyzing cooperative games among organizations to increase their profits. It is quite clear, that the cooperation between companies reduces the transport costs and therefore increases the profit of players. This issue was discussed in (Zibaei et al., 2016). The heterogeneous Vehicle Routing Game was solved by Engeval et al. (2004).

Obviously, the shipping costs represent a large amount of the company´s costs of operation and one of the solution to reduce such costs is the cooperation between the logistic companies. Logistic companies create the alliances (coalitions) in which they cooperate with each other in customer´s service. One way to reduce these shipping costs is the better allocation of the customer within a coalition which means that customer can also be served from another depot, not from the central depot. The second way may be the acceptance of the assumption about the return of the vehicle to the starting node, where we assume that the vehicle within a coalition can be repeatedly reloaded at another depot (not the starting one). In this paper we will introduce the new models which describe the situation mentioned above and we will present the basic principle of their functions in the form of illustrative examples.

The formation of a coalition only makes a sense if the coalition behavior of companies provides to the customers (subjects) some kind of surplus (such as a reduction in shipping costs) in comparison to the situation in which the logistic companies acted independently. Obviously, logistic companies will join the coalition in such a case in which they gain some benefits through this approach. Therefore, it is important to determine the redistribution of surplus between the individual players so that the members of individual coalition are not motivated to emerge from the coalition. In terms of the Game Theory, these are the games with a transferable utility (payoff). We will use the Shapley´s value to redistribute the benefits, which is based on the a priori appreciation of each player´s position and strength in terms of the cooperation behavior.

2. COOPERATIVE VEHICLE ROUTING PROBLEM WITH HETEROGENEUS FLEET

We will formulate the mathematical model in the full, edged and appreciated graph $\bar{G} = (N, \bar{H})$. Let $N^{(1)} = \{d_1, d_2, \dots d_k\}$ is the set of nodes representing the central depots (centers) and $N^{(2)} = \{c_1, c_2, \dots c_m\}$ is a set of nodes representing the customers and $N = N^{(1)} \cup N^{(2)}$ is the set of all the nodes of the graph. We assume that in every depot is located the one type of vehicle with different capacity and the number of vehicles in the depots is not limited (it can also be interpreted that a car can make a several routes). Capacity of vehicle in individual depots can be labeled as $g_h, h \in N^{(1)}$. We will assume, that vehicles have to return back to its starting point (depot), after they came out from their depots. Let $\bar{H} \subset NxN$ represents the set of edges e_{ij}, $i, j \in N$ between all nodes i

and *j*. Each edge e_{ij} being assigned to a real number called d_{ij} also known as a price of the edge e_{ij}. Let this assignment be the shortest distance between nodes *i* and *j*. Each of the customers located at i, $i \in N^{(2)}$, require the import of a certain quantity of goods, generally denominated as $q_i, i \in N^{(2)}$. The goal is to determine the vehicle's routes, which will satisfy the requirements of all customers. Customer requirements will only be realized in the whole (if the vehicle serves the customer, its entire delivery requirement will be realized), with no vehicle capacity exceeded. The main goal is to minimize the total travelled distance. In the model we assume implicitly, that $q_i \leq \max\{g_h, h \in N^{(1)}\}$ for all $i \in N^{(2)}$ which means, that the size of each customer's requirement will not exceed the capacity at least one type of the vehicle.

Now we accept the assumption that the owners of individual depots are different subjects (players). Players are able to cooperate with each other and create the coalitions and reduce their shipping costs. We are considering that each player owns only one depot and also has his own customers, but the player's vehicles in coalition can also be used to serve customers assigned to another player in a possible coalition. The number of possible coalitions is $2^{k+1} - 1$ (where $k+1$ represents the number of players). Let $N_S^{(1)} \subset N^{(1)}$ be a set of coalitions of players. We will also divide a set of customers based on their membership to individual players, then the coalition S will customers labeled as $N_S^{(2)}$. Thus, the set $N_S = N_S^{(1)} \cup N_S^{(2)}$ is the set representing the depots and the customers of the coalition S.

In general, one way how to mathematically describe routing problems is using binary variables x_{ijh} $i, j \in N, h \in N^{(1)}, i \neq j$ that enable to model if the node *i* precedes node *j* in a route of the vehicle from the *h-th* depot. Further on, the variables $u_{ih}, i \in N^{(2)}, h \in N^{(1)}$ that based on the known Miller-Tucker-Zemlin formulation of Traveling Salesman Problem (1960). Those variables are related to cumulative demand of customers on one particular route.

We assume that vehicle has to return to its starting depot after serving all the customers. The routes of vehicles and new customer assignments can be obtained by using this model:

$$cost = \min f(\mathbf{X}, \mathbf{u}) = \sum_{i \in N} \sum_{\substack{j \in N \\ i \neq j}} \sum_{h \in N^{(1)}} d_{ij} x_{ijh} \tag{1}$$

$$\sum_{i \in N} \sum_{h \in N^{(1)}} x_{ijh} = 1, \; j \in N^{(2)}, \; i \neq j \tag{2}$$

$$\sum_{j \in N} x_{ijh} = \sum_{j \in N} x_{jih}, \; i \in N^{(2)}, h \in N^{(1)} \tag{3}$$

$$\sum_{j \in N^{(2)}} x_{iji} = \sum_{j \in N^{(2)}} x_{jii}, \; i \in N^{(1)} \tag{4}$$

$$\sum_{j \in N^{(2)}} x_{iji} = \sum_{j \in N^{(2)}} \sum_{h \in N^{(1)}} x_{ijh}, \; i \in N^{(1)} \tag{5}$$

$$u_{ih} + q_j - g_h\left(1 - x_{ijh}\right) \leq u_{jh}, \; i \in N, \; j \in N^{(2)}, \; h \in N^{(1)}, \; i \neq j \tag{6}$$

$$u_{ii} + q_j - g_i\left(1 - x_{iji}\right) \leq u_{ji}, \; i \in N^{(1)}, \; j \in N^{(2)}, \; i \neq j \tag{7}$$

$$u_{ih} \leq g_h, \; i \in N^{(2)}, \; h \in N^{(1)} \tag{8}$$

The scalar cost (1) represents the minimum value of the total travelled distance. Constraint set (2) guarantee that each customer will be visited exactly once and exactly by one vehicle. Conditions (3) a (4) ensure the balance of the route. Constraint set (5) provides the balance of the number of routes from the depot (if this depot is used). Constraints (6) a (7) are the sub-tour elimination conditions and together with the condition (8) ensure that the capacity of the vehicle in not exceeded.

A fundamental assumption for the model presented above is the return of the vehicle to the same center after the completion of the customer´s service. Obviously, the release of this assumption may lead to additional cost savings. Now let´s assume that the vehicles of each depots can be repeatedly reloaded at another depot, not the starting one (while observing the idea of Vehicle Routing Problems). Therefore, we must ensure that the vehicle that is refilled in another depot continues its route to serve customers. Let´s define a new variable:

- $z_{ijh} \geq 0 \; i, j \in N, i \neq j, h \in N^{(1)}$, which represent the order of visit of the edge (*i,j)* by the *h*-th vehicle**.**

We add the constraints to the model mentioned above

$$z_{iji} = x_{iji} \;,\; i, j \in N^{(1)} \tag{9}$$

$$z_{ijh} + 1 \leq z_{jlh} + M(1 - x_{ijh}) + M(1 - x_{jlh}) \;,\; i, j, l \in N, i \neq j, j \neq l, i \neq h, \; h \in N^{(1)}$$
(10)

Where M is a big positive number.

This assumption will allow the possible further cost reductions in the context of cooperative distribution.

3. EMPIRICAL RESULTS

Firstly, we are solving our modified cooperative model of Vehicle Routing Problem with heterogenous fleet (1) – (8). The data were obtained from work paper (see at [2]), where we chose the symmetric distance matrix, which respresents the distances of adresses between fifteen customers and three depots in Bratislava. We obtained the shortest distace matrix from origin data by Floyd algorithm.

Consider the net of 18 nodes. We will assume that there are 3 depots from which the vehicle can start its route. So, we consider the distribution problem with multiple depots, whereby we have 3 suppliers to serve the certain customers. Suppliers or players (owners of individual depots) are expressed as $N^1 = \{d_1, d_2, d_3\}$. Each player owns one depot with one type of vehicle. The different capacity of each vehicle is given by $g_{d_1} = 200$, $g_{d_2} = 220$ and $g_{d_3} = 230$. Customers, who are strictly assigned to the individual depots (players), will be marked as*:* $\{c_1, c_2, c_3, c_4, c_5\} \; for \; d_1$, $\{c_6, c_7, c_8, c_9, c_{10}\} \; for \; d_2$, $\{c_{11}, c_{12}, c_{13}, c_{14}, c_{15}\} \; for \; d_3$. In the case of the creation the coalition $S \subseteq N^{(1)}$ we know that there are exactly 7 possible coalitions between the players.

We solve the cooperative vehicle routing problem with heterogeous fleet by using the model (1) - (8) and (1)-(10) for the created coalitions *S*: {1}, {2}, {3}, {1,2}, {1,3}, {2,3}, and {1,2,3} by GAMS software. To obtain the optimal solution, we used the solver Cplex 12.2.0.0 on the personal computer INTEL® Core ™ 2 CPU, E8500 @ 3.16 GB RAM for

Windows 10. Our interest is to find optimal solutions by using the model of cooperative vehicle routing problem with heterogeous fleet (1)-(8) ad (1)-(10) and compare their results. Our main interest is to prove that there is a reduction in total shipping costs through mutual cooperation between suppliers.

Table 1. presents the total transport costs of individual coalitions obtained from model (1)-(8) with assumptions mentioned above. In this model, we assume that vehicle has to return to its starting depot after serving all the customers.

Table 1. Minimum transport costs with optimal routes of model (1)-(8)

Coalitions	Costs	Optimal routes of model (1)-(8)			Time processing
		Route from d_1	Route from d_2	Route from d_3	
S={1}	22.98	d_1-c_3-c_5-c_4-c_2-c_1-d_1			0.03
S={2}	15.32		d_2-c_8-c_{10}-c_9-c_7-c_6-d_2		0.02
S={3}	22.7			d_3-c_{13}-c_{14}-c_{12}-c_{11}-c_{15}-d_3	0.01
S={1,2}	32.8	d_1-c_2-c_1-d_1	d_2-c_6-c_3-c_5-d_2-c_8-c_7--c_9-c_4-c_{10}-d_2		0.97
S={1,3}	30.78	d_1-c_2-c_{12}-c_1-c_{11}-d_1		d_3-c_{13}-c_5-c_3-c_{14}-c_{15}-c_4-d_3	0.23
S={2,3}	29.71		d_2-c_6-c_{14}-c_{12}-c_{11}-c_8-d_2	d_3-c_{13}-c_7-c_9-c_{15}-c_{10}-d_3	0.45
S={1,2,3}	38.25	d_1-c_2-c_{12}-c_1-c_{11}-d_1	d_2-c_6-c_{14}-c_3-c_5-c_{13}-c_7-d_2	d_3-c_8-c_{10}-c_{15}-c_9-c_4-d_3	18.88

In the Table 2 we present the total transport costs of individual coalitions obtained from model (1)-(10) with two more extra constraints. In this model, we assume that the vehicles of each depots can be repeatedly reloaded at another depot, not the starting one.

Table 2. Minimum transport costs with optimal routes obtained from model (1)-(10)

Coalitions	Costs	Optimal routes of model (1)-(10)			Time processing
		Route from d_1	Route from d_2	Route from d_3	
S={1}	22.98	d_1-c_3-c_5-c_4-c_2-c_1-d_1			0.02
S={2}	15.32		d_2-c_8-c_{10}-c_9-c_7-c_6-d_2		0.03
S={3}	22.7			d_3-c_{13}-c_{14}-c_{12}-c_{11}-c_{15}-d_3	0.01
S={1,2}	29.4	d_1-c_{10}-c_4-c_9-c_7-c_8-d_2	d_2-c_5-c_3-c_6-c_2-c_1-d_1		1.11
S={1,3}	30.38	d_1-c_{14}-c_{12}-c_2-c_1-c_{11}-d_1		d_3-c_{13}-c_5-c_3-c_{15}-c_4-d_3	4.58
S={2,3}	29.29		d_2-c_6-c_{14}-c_{12}-c_{11}-c_8-d_3	d_3-c_{10}-c_{15}-c_9-c_{13}-c_7-d_2	3.83
S={1,2,3}	35.21	d_1-c_{10}-c_{15}-c_9-c_4-d_3	d_2-c_6-c_{12}-c_2-c_1-c_{11}-d_1	d_3-c_8-c_{13}-c_7-c_5-c_3-c_{14}-d_2	82.39

We can summarize various results. For example, if player d_1 cooperates with player d_2 and player d_3, their minimum total cost is 35.21 units (if we consider two extra constraints).

For the comparison, if we obtained the assumptions (9) and (10) to our model, the coalition {1, 2, 3} achieves lower shipping costs. We can also see that after accepting the constraints all amounts of costs are decreasing and we can accept that we obtained much better results.

There are many possible ways of the redistribution these benefits from cooperation in terms of Game Theory. We will use the Shapley´s value, which is based on the a priori appreciation of each player´s position and strength in terms of the cooperation behavior. Firstly, we calculate the cost savings of coalitions *S* in the case of a cooperative approach to the distribution problem. The cost savings of coalitions *S* can be calculate as the difference between the sum of player´s total individual costs of noncooperative behavior and the costs, if they cooperate between each other.

Table 3 presents the cost savings, which players can save in case of cooperation. We can also see the redistribution of these savings between the players in coalitions in the next columns. These redistribution is based on Shapley value.

Table 3. Redistribution of benefits by Shapley value

Coalitions	Costs	Total Individual costs	Costs savings	Redistribution of benefits		
				Player d_1	Player d_2	Player d_3
S={1}	22.98	22.98	0	0		
S={2}	15.32	15.32	0		0	
S={3}	22.7	22.7	0			0
S={1,2}	29.4	38.3	8.9	4.45	4.45	
S={1,3}	30.38	45.68	15.3	7.65		7.65
S={2,3}	29.29	38.02	8.73		4.365	4.365
S={1,2,3}	35.21	61	25.79	9.72	6.435	9.635

Based on Table 3, we can confirm that in all types of coalitions is sum of the total individual costs of each player higher than the total cost of the coalitions. Therefore, the players tend to cooperate with each other. For this reason, we also quantify the cost savings, which players can save in case of cooperation. It means that in case of cooperation behavior they can save together 25.79 units of costs. If owners of depots act individually, their transport costs are 61 units. Based on Shapley value, we obtain following results of redistribution the benefits. In the coalition S= {1, 2, 3} where all owners of depots cooperate with each other, the player d_1 saves 9.72 units, the player d_2 saves 6.435 units and player d_3 saves 9.635 units of shipping costs based on the a priori appreciation of each player´s position and strength in terms of the cooperation behavior.

3. CONCLUSION

In this paper, we focused on the cooperative Vehicle Routing Problem with heterogonous fleet assuming the cooperation between the players to minimize the total shipment costs. Our main aim was to compare the results obtained by solving our two models. In the first model (1)-(8), we assume that vehicle has to return to its starting depot after serving all the customers. In the second model (1)-(10), we assume that the vehicles of each depots can be repeatedly reloaded at another depot, not the starting one. Our main idea was to prove that there is a reduction in total transport costs through mutual cooperation between individual suppliers. By comparing our results, we have taken the decision that our modified model has produced much better results than the first model. So, we can state that if we accept the two more constraints about reloading the vehicle at another depot (not the starting one), we obtained better results.

ACKNOWLEDGMENT

This paper is supported by the project VEGA 1/0351/17 APPLICATION OF SELECTED MODELS OF GAME THEORY IN ECONOMIC PROBLEMS OF SLOVAKIA

This paper is supported by the Slovak research and development agency, grant no. SK-SRB-18-0009 "OPTIMIZING OF LOGISTICS AND TRANSPORTATION PROCESSES BASED ON THE USE OF BATTERY OPERATED VEHICLES AND ICT SOLUTIONS".

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A FUZZY-AHP APPROACH TO EVALUATE THE CRITERIA OF THIRD-PARTY LOGISTICS (3PL) SERVICE PROVIDER

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Abstract: *This paper deals with the criteria that should be taken into consideration when making a decision about Third-Party Logistics (3PL) service providers and their evaluation. Not all the criteria is equally important, so it is necessary to evaluate them in order to determine the priority and help the company to make a decision. The criteria for 3PL assessment were defined by consulting several experts in the field of logistics. It is very important to analyze and evaluate 3PL providers because there are a very large number of providers in the market and for the company it is very important to choose the right one, based on the relevant criteria. The methodology used for evaluation of the criteria is based on Fuzzy-AHP (Analytic Hierarchy Process) approach. This approach combines the Saaty's scale (which gives the value of most importance in the statements-criteria) and fuzzy logic (which deals with the linguistic statements). The main result of the paper is to rank the criteria by importance and direct it for the further research in the field of 3PL.*

Keywords*: Third-Party Logistics (3PL) Service Provider, Fuzzy-AHP approach, 3PL evaluation criteria*

1. INTRODUCTION

Third-Party logistics (3PL) providers have an important role in the logistics industry and represent a very important link between companies and customers. 3PL is a company organization dealing with the physical movement of a certain good between two points as well as a provision of additional value-added services such as warehousing, packaging, customs etc. More and more companies are moving from their own transport account to the accounts of external business partners (3PL). Nowadays, in the field of logistics, it is difficult to find the right external business partner, since the number of 3PL providers has increased significantly and continuous to grow. The other reason is that there is a huge amount of criteria that characterize 3PL and it is hard to make a decision about its

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evaluation and selection. It is especially important to pay attention to the criteria that characterize the external logistics partner. Not all criteria are equally important. Different companies are looking for providers through different criteria, all depending on their needs. The firm's competitiveness strategy and its external environment affect the selection criteria for 3PL, stated Menon et al. (2014). The criteria considered in this paper are determined by consulting several experts in the field of logistics.

According to Daugherty et al. (1996) the logistics service capabilities provided by a 3PL should include dedication to emergency assistance, ability to handle changes in environment, flexibility in meeting external needs, providing of emergency service, the ability to proposing solutions to potential problems, helping corporation in implementing cost reduction, analysis of problem solution, responding to unforeseen uncertain needs of operational situations, anticipating transportation problems, proposing counter measures when unable to provide service, and providing service or operational status report. All these possibilities should have a logistics provider to in order to be considered as a professional in the field of logistics. Önüt et al. (2009) emphasized that a company could greatly save costs, time and increase competitive advantage in the market by making the right decision about the logistics service provider. However, due to high competition in the market, it is a challenge when choosing an appropriate logistic provider, especially when bearing in mind that there are various criteria that characterize them. There are lots of factors affecting selection of the service provider according to Akman and Baynal (2014).

To evaluate 3PL service providers in better organizing their selection, a variety number of techniques is used in the literature. For example, Kannon et al. (2009) used the multi-criteria methods in Fuzzy environment to select the best 3PL reverse logistics service provider. In research mentioned, the authors combined the TOPSIS method and Fuzzy logic. Yang et al. (2010) were conducted the research based on LSP selection for AIR cargo by using the Analytic Network Process (ANP) method. As the main criteria involved are performance, features, reliability, conformance serviceability and perceived quality. Vijavargiya and Dey (2010) were used the AHP method for logistics service provider selection in India. They considered the criteria such as cost (inland transportation and ocean/air freight), delivery (schedule flexibility) and value-added services (clearing and forwarding and IT- Track and Trace). Kabir (2012) combined the Fuzzy-AHP approach with the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method for 3PL provider selection. The criteria, such as quality, cost and delivery time were taken into consideration.

The research paper discusses the importance of the criteria for selecting a third-party logistics provider and provides the methodology based on fuzzy-AHP approach. This methodology is very useful for determining the importance of the criteria. The rest of the paper is organized as follows: Section 2 gives a fuzzy-AHP methodology for solving the evaluation problem. In Section 3, the evaluation criteria for 3PL providers is done by using previously described methodology and the final rank of the criteria is obtained. After this section, there are some concluding remarks.

2. A FUZZY-AHP METHODOLOGY

In this paper, fuzzy-AHP methodology is used to evaluate the criteria for 3PL service provider. This methodology combines fuzzy logic, which is based on linguistic terms and statements and well-known AHP methodology developed by Saaty. The authors of this paper decided to use exact this method because of its simplicity. It may be emphasized that for experts it is much easier to state the importance of the criteria by linguistic statements than by numerical values. Linguistic variables in Fuzzy logic are represented by triangular numbers (Kilincci and Onal, 2011). Ayhan (2013) conducted the case study in a gear-motor company. In that study, he used a fuzzy-AHP methodology which includes 7 steps.

Step 1. Formulation a Fuzzy-AHP Saaty's Scale with linguistic terms (table 1).

Table 1. Fuzzy-AHP triangular scale

Classic Saaty's Scale	Linguistic terms	Fuzzy Scale (triangular scale)
1	Equally important	(1,1,1)
3	Weakly important	(2,3,4)
5	Fairly important	(4,5,6)
7	Strongly important	(6,7,8)
9	Absolutely important	(9,9,9)
2	Values designed for evaluation of so-called interphase	(1,2,3)
4		(3,4,5)
6		(5,6,7)
8		(7,8,9)

According to the appropriate linguistic terms, the decision maker uses the given fuzzy number on the right side of the scale. For example, if the decision maker states "Criterion 1 is strongly important than Criterion 2" then it takes the fuzzy triangular scale as (6,7,8). On the contrary, in the pairwise comparison matrix of the criteria, comparison of Criterion 2 to Criterion 1 will take the fuzzy triangular scale as (1/8, 1/7, 1/6). The pairwise comparison of the criteria presented in the form of matrix is given in equation 1.

$$\tilde{P}_k = \left[\tilde{Z}_{11}^k \; \tilde{Z}_{12}^k \; \dots \; \tilde{Z}_{1n}^k \; \tilde{Z}_{21}^k \; \tilde{Z}_{22}^k \; \dots \; \tilde{Z}_{2n}^k \; \dots \; \dots \; \tilde{Z}_{ij}^k \; \dots \; \tilde{Z}_{n1}^k \; \tilde{Z}_{n2}^k \; \dots \; \tilde{Z}_{nn}^k \right] \tag{1}$$

where: $\tilde{Z}_{ij}^k$ indicates the *k-th* decision maker's preference of *i-th* criterion over *j-th* criterion, via fuzzy triangular numbers. Here, the sign "~" indicates the triangular number demonstration.

For example, $\tilde{Z}_{12}^2$ represents the second decision maker's preference of first criterion over second criterion and equals to $\tilde{Z}_{12}^2 = (6,7,8)$. If there is more than one decision maker, preferences of each decision maker $(\tilde{Z}_{ij}^k)$ are averaged and $\tilde{Z}_{ij}$ is calculated on the following way, given in equation 2.

$$\tilde{Z}_{ij} = \sum_{k=1}^{k} \frac{\tilde{Z}_{ij}^k}{k} \tag{2}$$

Step 2. According to averaged preferences, pairwise contribution matrix is updated as it shown in equation 3.

$$\tilde{P} = \left[\tilde{Z}_{11} \; \tilde{Z}_{12} \; \dots \; \tilde{Z}_{1n} \; \tilde{Z}_{21} \; \tilde{Z}_{22} \; \dots \; \tilde{Z}_{2n} \; \dots \; \dots \; \tilde{Z}_{ij} \; \dots \; \tilde{Z}_{n1} \; \tilde{Z}_{n2} \; \dots \; \tilde{Z}_{nn} \right] \tag{3}$$

where: $\tilde{P}$ represents pairwise contribution matrix.

Step 3. Geometric mean of fuzzy comparison values. It is done according to Buckley (1985) in equation 4.

$$\tilde{t}_i = (\prod_{j=1}^{n} \tilde{Z}_{ij})^{1/n}; \quad i=1,2,\ldots n; \tag{4}$$

where: $\tilde{t}_i$ represents geometric mean of fuzzy comparison values, $\Pi_{j=1}^{n}\tilde{Z}_{ij}$ is multiplied of each fuzzy value from pairwise comparison matrix.

Step 4. The fuzzy weights of each criterion

It is shown in equation 5 including the following three sub-steps:
Step 4.1 Find the vector summation of each $\tilde{t}_i$

Step 4.2 Find the (-1) power of summation vector. Replace the fuzzy triangular number to make it in an increasing order.

Step 4.3 To find the fuzzy weight of criterion i $(\widetilde{W}_i)$, it's necessary to multiply each $\tilde{t}_i$ with this reverse vector.

$$\widetilde{W}_i = \tilde{t}_i(\tilde{t}_1 \oplus \tilde{t}_2 \ldots \tilde{t}_n)^{-1} = \{eW_i, fW_i, gW_i\} \tag{5}$$

where: eW_i, fW_i and gW_i are obtained fuzzy triangular numbers

Step 5. Since $\widetilde{W}_i$ are still fuzzy triangular numbers, they need to be de-fuzzified by Center of Area method. This method is proposed by Chou and Chang (2008), via applying the equation 6.

$$M_i = \frac{e\widetilde{W}_i + f\widetilde{W}_i + g\widetilde{W}_i}{3} \tag{6}$$

where Mi represents a non-fuzzy number.

Step 6: Now, Mi, calculated beyond in equation 6 is a non-fuzzy number, but it needs to be normalized by following equation 7.

$$N_i = \frac{Mi}{\sum_{i=1}^{n} Mi} \tag{7}$$

where: Ni represents the final weights after normalization.

These 6 steps are performed to find the normalized weights of both criteria and the sub-criteria. Then by multiplying each sub-criteria weight with related criteria, the scores for each sub-criteria is calculated. According to these results, the sub-criteria with the highest score is suggested to the decision maker.

3. APPLICATION OF THE PROPOSED METHODOLOGY TO EVALUATE THE IMPORTANCE OF CRITERIA FOR 3PL PROVIDER SELECTION

In this paper, the previously described methodology is used to evaluate the importance of criteria that should be taken into consideration when the company makes a decision about 3PL provider selection. Several experts in the field of logistics and supply chain management were consulted and based on their opinion, the authors have given the weights for all criteria. Other words, not all criteria are equally important. In the continuation of the paper, the criteria that should be of huge importance is going to be described and evaluated. The authors distinguished the following criteria.

Criterion 1. Total cost of logistics outsourcing - this criterion is one of the most important for a logistics company according to the authors' opinion. In the context of the total logistic cost of outsourcing the authors included transport cost, low cost distribution, cost reduction, cost of warehousing, expected leasing cost and cost savings.

Criterion 2. Delivery - this criterion may be represented by attributes such as delivery speed, on-time delivery rate, accuracy of transit/delivery time, on-time performance, on-time shipment and delivery etc.

Criterion 3. Reliability – this criterion means the ability to perform the promised service dependably and accurately. It should be of huge importance for the company for whom the 3PL service provider provides services.

Criterion 4. Flexibility – this is related to ability to adapt to changing customers' requirements. Keeping flexibility in mind, it will include the ability to meet future requirements, the capacity to accommodate and grow the client's business, the capability to handle specific business requirements, time response capability etc.

Criterion 5. Professionalism – from the authors' point of view, this is also one of the most important criteria when make a decision about exact 3PL provider. If the 3PL provider is an expert in providing logistics services, a company will be more confident and easier to cooperate with. This criterion is characterized by attributes such as expertise, competence, and experience. Also, 3PL provider have to show to exhibit sound knowledge of services in the industry, display punctuality and courtesy towards their customers in the way they interact and present to the customers.

Criterion 6. Connection with other transport modes – it is very important to emphasize this criterion. The 3PL provider will be more respectable from the company if it does not use only one transport mode. The 3PL provider will be more respectable for the company if it does not use only one transport mode. The flow of goods can be even faster and logistics services can be made even cheaper.

Criterion 7. Social responsibility – is an important criterion in every field of business and should not be neglected. According to Yu (2016) social responsibility means to enterprise behavior that conforms to the existing social regulations, values and expectations. The same author also emphasized that businesses, nowadays, want to increase efficiency and reduce costs, while also bearing in mind that "green logistics" is a key theme for the future regarding to social responsibility.

Criterion 8. Reputation – This criterion is more relevant in the initial screening of Third-Party Logistics providers. The opinion of the customers about how good are 3PL providers is in satisfying their needs is one important factor when the company evaluate and select them.

Criterion 9. Information and equipment system – This criterion is of huge importance for each 3PL provider. This corresponds to physical equipment and IT system that has a 3PL in order to facilitate communication and logistics operations of its customers. It is related to Electronic Data Interchange (EDI), track & trace technology capabilities, information accessibility, materials handling equipment, security of information system etc.

Criterion 10. Quality – According to experts, this criterion can not be omitted because it encompasses many aspects such as quality of service, commitment to continuous improvement, standard environment issues, risk management etc.

After describing the criteria, the authors approach to their assessment using a well-explained fuzzy-AHP method in Section 2. First, we do the assessment criteria by using the fuzzy-AHP triangular scale. It is given in table 2.

Table 2. Criteria for an assessment by using fuzzy-AHP triangular scale

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	(1,1,1)	(2,3,4)	(3,4,5)	(4,5,6)	(2,3,4)	(4,5,6)	(4,5,6)	(6,7,8)	(2,3,4)	(1,2,3)
C2	(0.25,0.33,0.5)	(1,1,1)	(0.16,0.2,0.25)	(1,2,3)	(2,3,4)	(4,5,6)	(4,5,6)	(6,7,8)	(1,2,3)	(3,4,5)
C3	(0.16,0.2,0.25)	(4,5,6)	(1,1,1)	(6,7,8)	(4,5,6)	(2,3,4)	(6,7,8)	(8,9,10)	(4,5,6)	(2,3,4)
C4	(0.16,0.2,0.25)	(0.33,0.5,1)	(0.13,0.14,0.16)	(1,1,1)	(1,2,3)	(2,3,4)	(4,5,6)	(6,7,8)	(3,4,5)	(5,6,7)
C5	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(0.16,0.2,0.25)	(0.33,0.5,1)	(1,1,1)	(0.25,0.33,0.5)	(2,3,4)	(8,9,10)	(3,4,5)	(5,6,7)
C6	(0.16,0.2,0.25)	(0.16,0.2,0.25)	(0.25,0.33,0.5)	(0.25,0.33,0.5)	(2,3,4)	(1,1,1)	(4,5,6)	(6,7,8)	(1,2,3)	(0.16,0.2,0.25)
C7	(0.16,0.2,0.25)	(0.16,0.2,0.25)	(0.13,0.14,0.16)	(0.16,0.2,0.25)	(0.25,0.33,0.5)	(0.16,0.2,0.25)	(1,1,1)	(2,3,4)	(2,3,4)	(0.13,0.14,0.16)
C8	(0.13,0.14,0.16)	(0.13,0.14,0.16)	(0.1,0.11,0.13)	(0.13,0.14,0.16)	(0.1,0.11,0.13)	(0.33,0.5,1)	(0.25,0.33,0.5)	(1,1,1)	(0.16,0.2,0.25)	(8,9,10)
C9	(0.25,0.33,0.5)	(0.33,0.5,1)	(0.16,0.2,0.25)	(0.20,0.25,0.33)	(0.2,0.25,0.33)	(0.33,0.5,1)	(0.25,0.33,0.5)	(4,5,6)	(1,1,1)	(6,7,8)
C10	(0.1,0.11,0.13)	(0.16,0.2,0.25)	(0.25,0.33,0.5)	(0.14,0.16,0.2)	(0.14,0.16,0.2)	(4,5,6)	(6,7,8)	(0.1,0.11,0.13)	(0.13,0.14,0.16)	(1,1,1)

The next step proposed by the methodology is to find a fuzzy geometric mean of given values. This is calculated according to equation 4 and it is proposed in Table 3.

Table 3. A Fuzzy Geometric mean value for each criterion

Criterion	$\tilde{t}_i$	Values
C1	i=1	(2.26, 3.37, 4.18)
C2	i=2	(1.37, 1.88, 2.40)
C3	i=3	(2.55, 3.15, 3.75)
C4	i=4	(1.17, 1.53, 1.95)
C5	i=5	(0.85, 1.08, 1.46)
C6	i=6	(0.64, 0.84, 1.08)
C7	i=7	(0.34, 0.39, 0.49)
C8	i=8	(0.28, 0.32, 0.39)
C9	i=9	(0.50, 0.64, 0.89)
C10	i=10	(0.39, 0.46, 0.59)

Following the sub-steps of the step 4, we obtained fuzzy-weights and it is represented in Table 4.

Table 4. Obtained fuzzy weights

$\widetilde{Wf}1$	(0.14, 0.24, 0.38)
$\widetilde{Wf}2$	(0.08, 0.13, 0.22)
$\widetilde{Wf}3$	(0.15, 0.22, 0,34)
$\widetilde{Wf}4$	(0.07, 0.11, 0.18)
$\widetilde{Wf}5$	(0.06, 0.08, 0.13)
$\widetilde{Wf}6$	(0.04, 0.06, 0.10)
$\widetilde{Wf}7$	(0.02, 0.02, 0.04)
$\widetilde{Wf}8$	(0.02, 0.02, 0.04)
$\widetilde{Wf}9$	(0.03, 0.04, 0.08)
$\widetilde{Wf}10$	(0.02, 0.03, 0.05)

In Table 4, obtained $\widetilde{W}_i$ are still fuzzy-triangular numbers, they need to be de-fuzzyfied by the center of area method. This is done by using the equation 6 and the following table represents a non-fuzzy numbers.

Table 5. De-fuzzification by using the Center of Area

Criterion	Center of Area
C1	0.25
C2	0.14
C3	0.23
C4	0.12
C5	0.09
C6	0.20
C7	0.02
C8	0.02
C9	0.05
C10	0.03
	1.16

After this procedure, by using non-fuzzy Mi's, the normalized weights and the rank of each criterion are calculated and given in Table 6.

Table 6. Obtained criteria weights and the final rank

	Criterion	Weights	Rank
C1	Total cost of logistics outsourcing	0.22	1.
C2	Delivery	0.12	4.
C3	Reliability	0.20	2.
C4	Flexibility	0.10	5.
C5	Professionalism	0.08	6.
C6	Connection with other transport modes	0.17	3.
C7	Social responsibility	0.02	10.
C8	Reputation	0.02	9.
C9	Information and equipment system	0.04	7.
C10	Quality	0.03	8.

4. CONCLUSION

Third-Party Logistics (3PL) service providers represent a very important part of the logistics and supply chain. Nowadays, more and more companies outsource their own activities to 3PL. However, the process of selection of 3PL is affected by a numerous criteria that each company should take into consideration. Depending on the business the company is dealing with, various types of criteria should be distinguished by the logistics provider that is needed by the company. However, there are some criteria such as cost, delivery, quality etc. that are always significant and considered by the companies which selects the provider. In addition, there are many other criteria for the selection and evaluation of 3PL. Not all criteria are equally important. Companies should consider some criteria in more detail in order to keep business efficiently.

The main objective of this paper is to evaluate the criteria that characterize 3PL service providers. For this reason, the Fuzzy-AHP methodology is used to evaluate the criteria by importance. This methodology is particularly suitable, because it combines Saaty's scale with Fuzzy logic, which deals with the linguistic terms and statements.

For the evaluation process, 10 criteria are taken into consideration and the authors of this paper came to the following conclusion (given in Table 6): the highest importance while selecting 3PL provider is attributed to the total cost of logistics outsourcing with value of 0.22. The second and third place are devoted to reliability and connection with other transport modes, respectively. The criterion of delivery with participation of 0.12 is at the fourth place. The criterion related to the flexibility is also of huge importance and participates with the weight of 0.10. The last five criteria related to the professionalism, Information and equipment system, quality, reputation and social responsibility respectively, should not be neglected, but in this paper, there are lesser values attached to them.

This paper gives an insight into the evaluation criteria problem for 3PL selection. Future research should be done to select the best 3PL service provider for outsourcing activities. A direction for future research may be a further adjustment of the methodology. The selection of the 3PL, based on our research, should be done by using some of the multi-criteria analysis methods such as TOPSIS, ELECTRE, Promethee etc.

ACKNOWLEDGMENT

This research paper was supported by SGS_2019_010.

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FUZZY LOGIC APPLICATION IN GREEN TRANSPORT - PREDICTION OF FREIGHT TRAIN ENERGY CONSUMPTION

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Abstract: *Rail freight transport is one of the most preferred modes of green transport since it emits three times less CO_2 and particulates per ton-mile than road transport. Train energy consumption is the biggest issue related to rail traction costs. Data about freight trains energy consumption per year are not possible to define precisely, so it is convenient to use fuzzy logic as a tool for data prediction. In order to predict it, we provide Wang - Mendel method for combining both numerical and linguistic information into a common framework – a fuzzy rule base. Relevant input variables are: freight train kilometers, average freight trains weight and non-productive kilometers. The output variable from the defined fuzzy logic system is average energy consumption per year for rail freight transport. The proposed model is applied and tested on real data collected in the Republic of Serbia.*

Keywords: *Train energy consumption; Rail freight transport; Prediction model; Wang-Mendel method; Fuzzy rules.*

1. INTRODUCTION

The term green logistics represents all efforts to manage and minimize the ecological impact of logistics activities. The main aim of this concept is moving and delivering goods with the lowest cost, but with the highest standards and minimal environmental impact.

In that sense, rail freight transport is one of the most preferred modes of transport since it emits three times less CO_2 and particulates per ton-mile than road transport. Besides these ecological benefits, rail transport is the most cost-effective mode of transport.

Rail transport gives the most important contribution to the green logistic concept, compared to all transport modes, because it is the least harmful to the environment. Table 1 shows date given in the studies for the years 2000 and 2008. In both studies, rail freight transport has the lowest external costs. One can notice that all modes of transport significantly decreased external cost in 2008 compared with the cost in 2000.

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Table 1. Average external costs - EU-27 Member States (Periods: 2000 and 2008) [€/tonne km]

	INFRAS/IWW, 2004	CE/INFRAS/ISI, 2011
	for 2000	for 2008
HDV	71.2	34
Road freight total	87.8	50.5
Rail freight	17.9	7.9
Inland waterways	22.5	11.2

Data source: CE Delft, Infras, Fraunhofer ISI, 2011

Figure 1 shows a comparison of the external cost road and inland waterway modes of transport with the external cost of rail transport. Figure 1 gives a ration of these costs. One can notice that ration for HDV (heavy duties vehicles) is increased from 3.98 in 2000 to 4.3 in 2008. The biggest difference in the rations is for road freight total (from 4.91 in 2000 to 6.39 in 2008). Rations for inland waterways are the smallest in the both years (1.26 in 2000 and 1.42 in 2008). Figure 2 gives a structure of external costs in 2008.

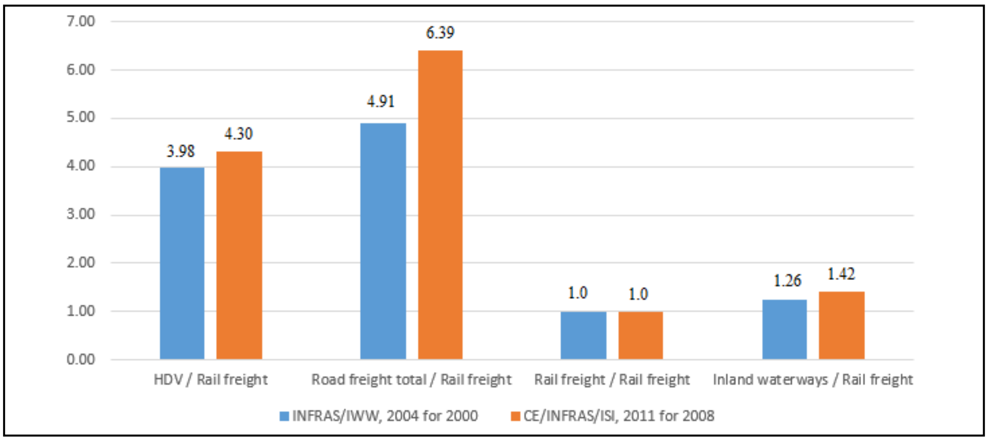

Figure 1. Average cost ration compared to rail (freight transport)
Data source: CE Delft, Infras, Fraunhofer ISI, 2011

Table 1 and Figures 1 and 2 show the advantages of the railway transport mode, which lead to an evident growth in rail freight logistics such as: cheap transport when compared to other modes of transport; more efficient as it allows larger volume of cargo transport to long distances; the transport of goods by train reduces the amount of fuel and emissions; the rail transport is considered to be six to seven times more efficient than road transport and reduces emissions by ~30-70%. The road transport is still dominant mode of transport in most of the countries around the world. However, some facts (increasing road congestion, costs, and emissions of CO_2) change the focus toward the railway transport.

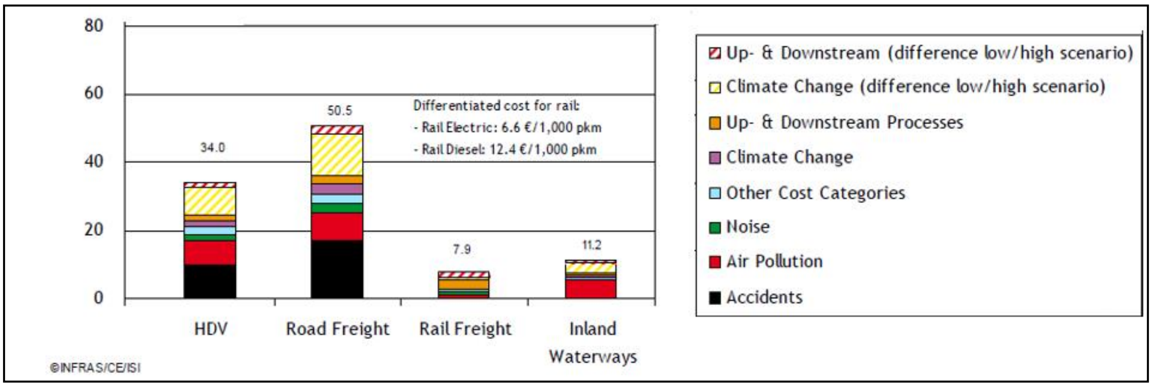

Figure 2. Structure of external costs (freight transport for 2008)
Data source: CE Delft, Infras, Fraunhofer ISI, 2011

The objectives of UIC (The International Union of Railways) are the rail share of freight land transport to be equal with the road and reducing specific average CO_2 emissions from train operations by 50% reduction by 2030. A consequence of these objectives is the energy consumption increasing. Train energy consumption is a basic and the biggest issue related to the rail traction costs. Data about freight trains energy consumption per year are not possible to define precisely, so it is convenient to use fuzzy logic as a tool for data prediction. In a defined problem, fuzziness appears due to the lack of ability of exactly predicting certain values.

In this paper, the model for train energy consumption prediction is developed. In order to forecast freight train energy consumption per year, we provide Wang-Mendel method for combining both numerical and linguistic information into a common framework – a fuzzy rule base. Relevant input values are: *freight trains kilometres*, *average freight trains weight*, *non-productive kilometres*. The output value from a defined fuzzy logic system is *average energy consumption* per year for rail freight transport. The proposed model is applied and tested on real data collected in the Republic of Serbia.

The paper is organized as follows. After Introduction, in Section 2, brief literature review is given. The developed model for determination of electric energy consumption for freight trains traction is presented in Section 3. Section 4 is dedicated to the case study, i.e. to the application of presented model on Serbian railway network. Last Section presents conclusions and future research directions.

2. BRIEF LITERATURE REVIEW

Wang Mendel method generates fuzzy rules from examples. Giving the literature review of the fuzzy systems in the transportation fields, Teodorović (1999) referred several papers with Wang Mendel method applications. Teodorović (1999) emphasized that Wang Mendel method represents a nonlinear mapping, with the possibility to approximate any real continuous function to arbitrary accuracy. Wang (2003) extended this method to enhance the practicality. The author presented the approach for ranking the importance of input variables and proposed an algorithm for solving pattern recognition problems. Chen et al. (2007) emphasized that Wang Mendel rule generation method is the one of the earliest algorithms, but with one disadvantage. This method selects the rules with the maximum degree, without taking into consideration other conflicting rules. The authors compared three methods, and the main conclusion of the paper is that the weighted mean method has the best robustness and error-tolerance, consequently this approach is suitable for extracting rules from the real data with noise. The results obtained by Yanar and Akyurek (2011) indicated that Wang Mendel method provides better starting configuration for simulated annealing compared to fuzzy C-means clustering method.

Wang Mendel method was used for energy consumption forecasting in Jozi et al. (2017). Results showed that the proposed method using the combination of energy consumption data and environmental temperature is able to provide more reliable forecasts for the energy consumption than several other methods experimented before, namely based on artificial neural networks and support vector machines. Authors Yang et al. (2010) presented an improved Wang Mendel method for electric load forecasting. They combined this approach with particle swarm optimization.

3. MODEL FOR PREDICTION OF ELECTRIC ENERGY CONSUMPTION FOR FREIGHT TRAINS TRACTION

Electric energy consumption for freight trains traction depends on various parameters such as: the utilization factor of the overhead line and the electrical substations, the power of the locomotive, the corrected virtual coefficient, train speed, the length of the section and the specific electric energy consumption per power. Since we do not have access to all these data, we apply Wang-Mendel method (Wang and Mendel, 1992) on the data which are available.

In order to predict the consumption of electric energy for the traction of freight trains on an annual basis, we take into account the following:

- Input variables:

1. *Trains kilometres -TK [km]* - It represents the number of kilometres that all electric locomotives passed by hauling freight trains, during one year. The greater the number of kilometres travelled, the greater the consumption of electric energy. Data are given annually.
2. *Average weight of trains - AWT [tonne]* - It provides information on how much a freight train is loaded on average. Electric locomotive hauling heavy freight trains consumes more electric energy. Data are given annually.
3. *Non-productive kilometres - NPK [km]* - The number of kilometres travelled by electric locomotives when they are out of the traction, or when they are not at the front of a train. Data are given annually.

- Output variable:

1. *Average energy consumption - AEC [kWh]* - It represents the amount of electric energy consumed by all the locomotives while they performed freight trains traction. Data are given annually.

For the implementation of Wang-Mendel model, it is necessary to have appropriate numerical data about the input and output variable (Table 2). As it can be noticed each set of desired input-output data is given in the form of: $\{(x_1^{(1)}, x_2^{(1)}, x_3^{(1)}; y^{(1)}), (x_1^{(2)}, x_2^{(2)}, x_3^{(2)}; y^{(2)}), \ldots, (x_1^{(8)}, x_2^{(8)}, x_3^{(8)}; y^{(8)})\}$.

Table 2. Values of input and output variables, in the 2007-2014 period†

Year	*TK*	*AWT*	*NPK*	*AEC*
2007	4 909 390	943	957 821	132 722 827
2008	6 890 035	1018	973 953	172 117 737
2009	6 547 541	1150	1 044 119	153 103 010
2010	5 091 884	998	841 230	114 569 156
2011	5 152 954	1100	690 245	118 585 848
2012	4 057 087	971	761 418	92 500 913
2013	4 628 479	912	693 911	110 200 700
2014	5 851 905	840	995 357	112 093 124

In the first step of Wang Mendel method, input and output spaces are divided into fuzzy regions. Assume that the domain intervals of x_1, x_2, x_3 and y are $[x_1^-, x_1^+]$, $[x_2^-, x_2^+]$, $[x_3^-, x_3^+]$ and $[y^-, y^+]$, respectively. We divide each domain interval into $2N+1$ regions (N may vary from variable to variable) and assign each region a fuzzy membership (Table 3).

Table 3. Variable domains

Variable	Domain
Trains kilometres	[3.5, 7]‡
Average weight of trains	[700, 1300]§
Non-productive kilometres	[500, 1200]**
Average energy consumption	[80, 180]††

The domain division for the variable "*Trains kilometres*" has been done into 3 fuzzy sets (Figure 3):

- Small [3.5, 3.5, 4, 5] - represents a small volume of the freight train kilometres.
- Medium [4, 5, 6] - represents a medium volume of the freight train kilometres.
- Large [5, 6, 7, 7] - represents a large volume of the freight train kilometres.

† data collected in the Republic of Serbia.
‡ domain is expressed in million km.
§ domain is expressed in tonnes.
** domain is expressed in thousand km.
†† domain is expressed in million kWh.

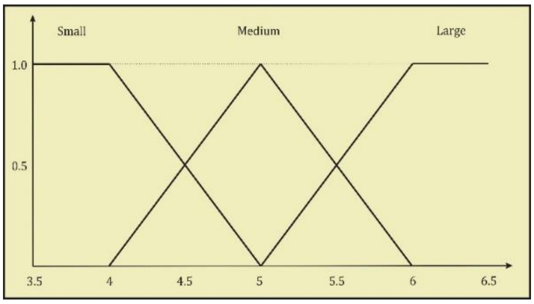

Figure 3. Membership functions of "*Trains kilometres*" fuzzy variable

The domain division for the variable "*Average weight of trains*" has been done in same way. Domain division is shown in Figure 4:

- Light [700, 700, 800, 900] - represents a light weight of freight trains.
- Medium [800, 100, 1200] - represents a medium weight of freight trains.
- Heavy [1100, 1200, 1300, 1300] - represents a heavy weight of freight trains.

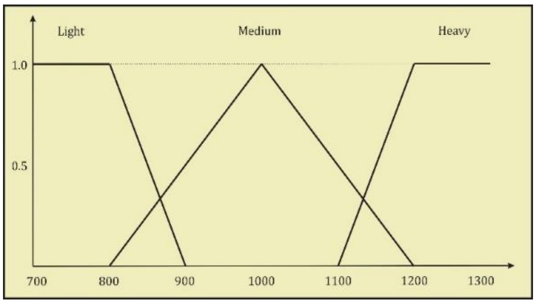

Figure 4. Membership functions of "*Average weight of trains*" fuzzy

For the variable "*Non-productive kilometres*" domain has been divided in three fuzzy sets (Figure 5):

- Small [500, 500, 600, 800] - represents a small amount of non-productive locomotive kilometres.
- Medium [600, 800, 1000] - represents a medium amount of non-productive locomotive kilometres.
- Large [800, 1000, 1200, 1200] - represents a large amount of performed non-productive locomotive kilometres.

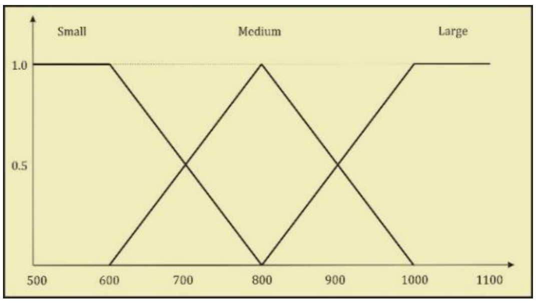

Figure 5. Membership functions of "*Non-productive kilometres*" fuzzy variable

Finally, it is necessary to cover a domain for "*Average energy consumption*" fuzzy variable (Figure 6) with the membership functions. The division has been carried out on 5 intervals.

- Very low [80, 80, 100] - represents a very low energy consumption.
- Low [90, 100, 120] - represents a low energy consumption.
- Medium [100, 120, 140] - represents a medium energy consumption.
- High [120, 140, 160] - represents a high energy consumption.
- Very High [140, 160, 180, 180] - represents a very high energy consumption.

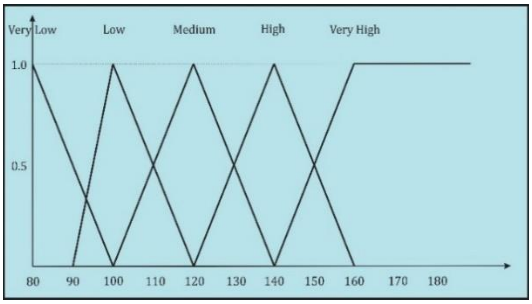

Figure 6. Membership functions of the output variable "*Average energy consumption*"

In the next step of Wang-Mendel method, the generation of the fuzzy rules should be done, based on numerical data. For each of the input-output pair, it is necessary to determine the membership degree to fuzzy sets that cover some of the intervals. After the membership degree determination, the considered values join that fuzzy set to which they belong with the highest membership degree (Teodorović and Šelmić, 2012).

Finally, we obtain one rule from one pair of desired input-output data, e.g.:

($x_1^{(1)}$, $x_2^{(1)}$, $x_3^{(1)}$; $y^{(1)}$) =›[$x_1^{(1)}$(4.9 in **Medium**, max), $x_2^{(1)}$ (943 in **Medium**, max), $x_3^{(1)}$ (957.821 in **Large**, max); $y^{(1)}$ (132.7 in **High**, max)] =› **Rule 1**.

Rule 1: IF x_1 is **Medium** and x_2 is **Medium** and x_3 is **Large**, THEN y is **High**

After this procedure we made 8 fuzzy rules, the one for each input-output pair of data.

The fuzzy rules obtain from numerical data are given below:

- If "*TK*" is **Medium** and "*AWT*" is **Medium** and "*NPK*" is **Large** then "*AEC*" is **High**;
- If "*TK*" is **Large** and "*AWT*" is **Medium** and "*NPK*" is **Large** then "*AEC*" is **Very High**;
- If "*TK*" is **Large** and "*AWT*" is **Heavy** and "*NPK*" is **Large** then "*AEC*" is **Very High**;
- If "*TK*" is **Medium** and "*AWT*" is **Medium** and "*NPK*" is **Medium** then "*AEC*" is **Medium**;
- If "*TK*" is **Medium** and "*AWT*" is **Heavy** and "*NPK*" is **Small** then "*AEC*" is **Medium**;
- If "*TK*" is **Small** and "*AWT*" is **Medium** and "*NPK*" is **Medium** then "*AEC*" is **Low**;
- If "*TK*" is **Medium** and "*AWT*" is **Medium** and "*NPK*" is **Small** then "*AEC*" is **Medium**;
- If "*TK*" is **Large** and "*AWT*" is **Light** and "*NPK*" is **Large** then "*AEC*" is **Medium**;

Next step is to check all obtained rules and to eliminate same or conflict rules, i.e. rules that have same IF part but a different THEN part. In this example all defined rules are correct, there are no conflict or same rules.

Most often, available pairs of input-output data are not sufficient to "cover" all the different situations that can happen in a particular system. Fuzzy rule base is more complete if the number of different input-output data pairs is bigger. In order to obtain better results fuzzy rule base may be amended with additional fuzzy rules generated by an expert. The final fuzzy rule base in the case of prediction of freight train average energy consumption in Serbia is shown in Table 4. Fuzzy rules generated by the experts are underlined.

Table 4. Final fuzzy rule base

	***TK*-Small**			***TK*-Medium**			***TK*-Large**		
	***AWT* small**	***AWT* medium**	***AWT* heavy**	***AWT* small**	***AWT* medium**	***AWT* heavy**	***AWT* small**	***AWT* medium**	***AWT* heavy**
***NPK* small**	<u>Very low</u>	<u>Very low</u>	<u>Low</u>	<u>Low</u>	Medium	Medium	<u>Medium</u>	<u>High</u>	<u>Very high</u>
***NPK* medium**	<u>Very low</u>	Low	<u>Low</u>	<u>Low</u>	Medium	<u>High</u>	<u>Medium</u>	<u>High</u>	<u>Very high</u>
***NPK* large**	<u>Very low</u>	<u>Low</u>	<u>Low</u>	<u>Medium</u>	High	<u>Very high</u>	Medium	Very high	Very high

4. CASE STUDY – RESULTS AND DISCUSSION

Considering the Serbian railway network, there is only 1278.7 km electrified railway lines that are one-third of the total network length (3735.8 km). The forecast of freight traffic on Serbian railway network (Figure 7) for period 2018-2022 shows an increase in freight traffic (Ćalić, 2018), and it is considered that most of the forecasted transport of goods will be carried out on electrified lines, as they are main lines.

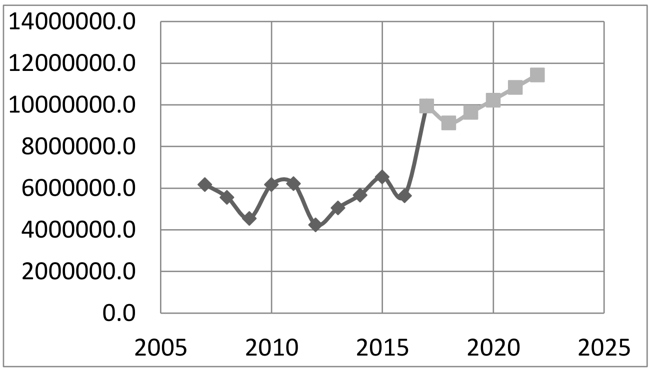

Figure 7. Forecast freight train transport for period 2018-2022, on Serbian railway networks

In order to test our model we apply the following input data (for year 2013):

- TK = 4.628 million kilometres,
- AWT = 912 tonnes,
- NPK = 693.911 thousand kilometres.

After defuzzification process, for which the centre of gravity is used, the output value is obtained: *AEC* is 109 million kWh.

Table 5 shows comparison of the results between real data and the one obtained from Wang - Mendel method.

Table 5. Comparison of the results

Year	*TK* [mil km]	*AWT* [tonne]	*NPK* [thousands of km]	*AEC* [mil kwh]	*AEC using Wang Mendel* [mil kwh]	Deviation [%]
2007	4.909	943	957.821	132.723	133	0.21%
2008	6.890	1018	973.953	172.118	164	-4.95%
2009	6.547	1150	1 044.119	153.103	163	6.07%
2010	5.092	998	841.230	114.569	128	10.49%
2011	5.153	1100	690.245	118.586	125	5.13%
2012	4.057	971	761.418	92.501	103	10.19%
2013	4.628	912	693.911	110.201	109	-1.10%
2014	5.852	840	995.357	112.093	133	15.72%

From Table 5 and Figure 8 it can be seen that developed Wang - Mendel method is able to predict energy consumption within 10% deviation in 5 cases, in 2 cases deviations are near 10%, and in just one case deviation is close to 16%. These results are very encouraging for the further implementation of this model.

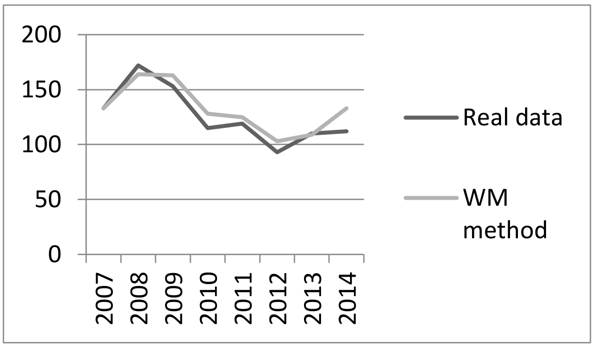

Figure 8. Comparison of the results

5. CONCLUSION

Electric energy consumption for rail freight transport is uncertain and hard to be predicted. When the data on energy consumption from previous period are available, Wang-Mendel method could be used to obtain fuzzy rules. However, fuzzy rules that could be defined according to data from the past most often do not reproduce all possible situations, which could emerge as a result of input variables membership functions combinations. This often leads to imprecision and inaccuracy.

This paper presents the model for prediction of freight train energy consumption. Relevant considered input are: *freight train kilometers, average freight train weight* and *non-productive kilometers*. The developed model is verified through the real data collected in the Republic of Serbia.

ACKNOWLEDGMENT

This work has been supported by Serbian Ministry of Education, Science and Technological Development through grants No. TR36002 and TR36022.

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A BI-OBJECTIVE APPROACH FOR DESIGNING END-OF-LIFE LITHIUM-ION BATTERIES LOGISTICS NETWORK

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Abstract: *This paper presents a bi-objective approach for designing logistics network for end-of-life lithium-ion batteries from electric vehicles. The first objective determines the optimal locations of collection points and treatment facilities, for collecting and processing of end-of-life lithium-ion batteries, with aim of minimizing total costs of the system. The second objective minimizes risk associated with transport of end-of-life lithium-ion batteries for end users located along the routes of transportation vehicles. Proposed model was tested on illustrative example.*

Keywords: *electric vehicles, lithium-ion batteries, logistics network design*

1. INTRODUCTION

Lithium-ion batteries (LIBs), have been used widely in many electronic devices like cell phones, laptops, leisure equipment, etc., due to its rechargeable nature. In recent years, LIBs have been used as a power source for electric vehicles, replacing nickel-metal hydride batteries (Wang et al., 2014). Electric vehicles are becoming popular worldwide, due to economical and environmental benefits (Figure 1). According to EEA (2018) there are several different electric vehicle types which includes: battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), range extended electric vehicles (REEVs), hybrid electric vehicles (HEVs) and fuel cell electric vehicles (FCEVs). The emphasis of this paper is on BEVs, defined as vehicles that uses electricity stored in an on-board battery and powered by an electric motor. Due to technologic development and environmental concerns, it is expected that production of LIBs will continue to grow. Only in EU, BEVs comprised around 0.6 % of all new car registrations in 2017 and by 2030, BEVs could be between 3.9 % and 13.0 % of new car registrations (EEA, 2018). This means that significant quantities of LIBs will enter the waste stream in the future, so some changes in logistics infrastructure as well end-of-life LIBs processing will be needed (Figure 2). For example, facilities for remanufacturing or recycling of LIBs must be located. That means that existing logistics infrastructure needs to be reorganized or new

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logistics infrastructure should be designed in order to deal with end-of-life LIBs in environmental and safe manner.

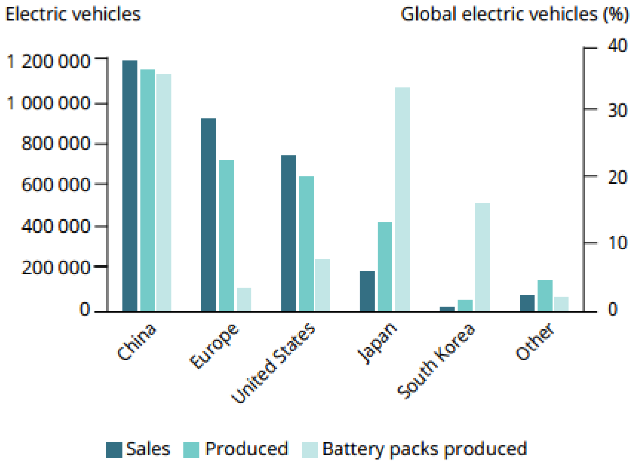

Figure 1. Number of light-duty passenger electric vehicles sold, produced, and battery packs produced between 2010 and 2017 (EEA, 2018)

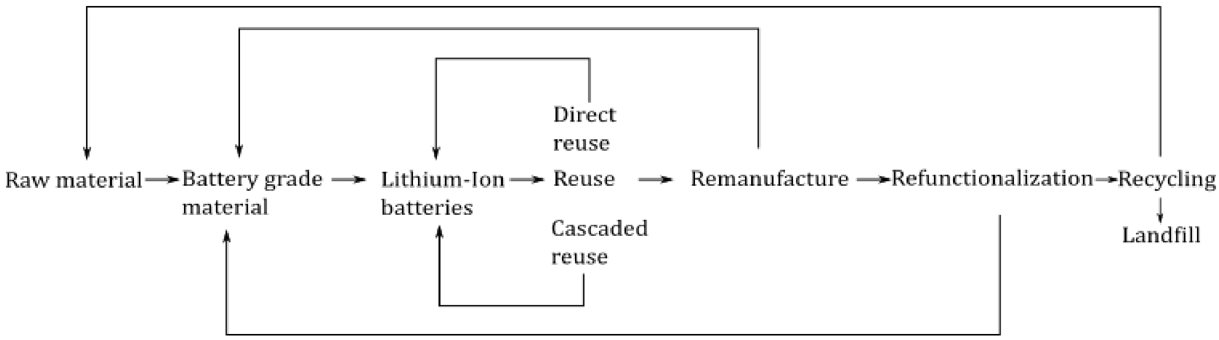

Figure 2. Options for the end-of-life stage of LIBs (EEA, 2018)

Since, end-of-life LIBs is relatively new waste stream there has been little incentive for the development of infrastructure and processes for recycling and reuse (EEA, 2018). Also, there aren't a lot of papers that can be found in the literature dealing with design of logistics infrastructure for end-of-life LIBs. Li et al. (2018) proposed a mathematical model for designing closed loop supply chain network model for LIBs remanufacturing considering different quality levels of spent battery. Authors developed an optimization model to maximize the network profit. Gu et al. (2018) optimized total profits in the EV battery supply chain in different batteries period of use, by developing the optimal pricing strategy between manufacturer and remanufacturer, discussed the relationships between return yield, sorting rate and recycling rate. Wang et al. (2014) developed an optimization model to analyze the profitability of recycling facilities, commodity market prices of materials expected to be recovered, and material composition for three common battery types. The majority of the paper dealing with end-of-life LIBs is concentrating on predicting quantities of end-of-life LIBs, remanufacturing and recycling process technologies, and investigating future demands of raw materials for LIBs manufacturing (Richa et al., (2014), Winslow et al. (2018)). On the other hand, LIBs falls in the category of dangerous goods according to the International Air Transport Association (IATA), requiring special handling (EPA, 2018). According to EPA (2018) LIBs technology is not intrinsically safe because short circuit, overcharge, over-discharge, crush, and high temperature can lead to thermal runaway, fire, and explosion. Hence, dangerous characteristics must be considered when designing logistics network for end-of-life LIBs. From here, the main attention of the paper is to present a possible approach for designing logistics networks for end-of-life LIBs. Two objectives are defined, where first one minimizes costs of establishing facilities as well transportation costs. The second objective minimizes the risk associated with transport of end-of-life LIBS for end users located along the routes of transportation vehicles. The rest of the paper is structured as follows. Description of the problem as well as mathematical formulation is presented in Section 2. In Section 3 an illustrative example is presented, while Section 4 summarizes findings and provides some thoughts regarding future research.

2. DESCRIPTION OF THE PROBLEM

Problem considered in this paper has following characteristics. End users as LIBs generators, are represented by population centers located at known sites *i*. It is assumed that v_i residents are located at site *i*, each one generating q_i units of LIBs. Also, it is assumed that generation of LIBs, has uniform distribution with parameters (500, 2500) like in Subula et al., (2015). All generated units of LIBs should be collected from end users and transported to treatment facility via collection points. Also, during the treatment process, some of the LIBs, due to number of reasons, could end up in the landfill site (Figure 3). In proposed model, we assumed that location of landfill is known, so no modeling parameters and variables for landfill is used.

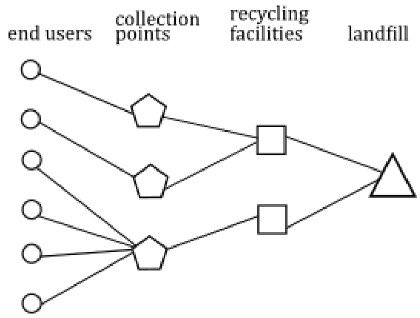

Figure 3. Modeled reverse logistics network for end-of-life LIBs

Following notation is used for mathematical formulation of the problem.
Sets:

$I = \{1, \ldots N_i\}$ end users zones (LIBs generators)

$K = \{1, \ldots N_k\}$ potential locations for collection points (CPs)

$J = \{1, \ldots N_{j+1}\}$ potential locations for treatment facilities plus disposal option

Parameters

α minimal disposal fraction of LIBs

G_k capacity of collection point *k*

G_j capacity of treatment facility *j*

C_{ik} transportation costs of transporting LIBs from to end users zones *i* to collection point *k*

C_{kj} transportation costs of transporting LIBs from collection point *k* to treatment facility *j*

C_{j+1} transportation costs of transporting LIBs from treatment facility *j* to landfill site j+1

Variables

X_{ik} fraction of LIBs quantities transported from end user zone *i* to collection site *k*

X_{kj} fraction of LIBs transported from collection point *k* to treatment facility *j*

X_{j+1} fraction of LIBs transported from treatment facility *j* to landfill site *j+1*

Y_k binary variable, Y_k=1 if collection point k is opened, otherwise Y_k =0

Y_j binary variable, Y_j =1 if treatment facility j is opened, otherwise Y_j =0

p_j - LIBs quantities transported to treatment site *j*

p_k- LIBs quantities transported to collection site *k*

Then, the formulation of the problem as a mixed integer linear programming problem is given by

min $$OF1 = \sum_k f_i y_k + \sum_j f_j y_j + \sum_i \sum_k C_{ik} X_{ik} + \sum_k \sum_j C_{kj} X_{kj} + \sum_j C_{j+1} X_{j+1} \quad (1)$$

min $$OF2 = \sum_i \sum_k v_{ik} X_{ik} + \sum_k \sum_j v_{kj} X_{kj} + \sum_{j+1} v_{j+1} X_{j+1} \quad (2)$$

s.t.

$$\sum_k X_{ik} = q_i, \forall i \quad (3)$$

$$\sum_i X_{ik} - \sum_j X_{kj} = 0, \forall k \quad (4)$$

$$(1-\alpha)\sum_k X_{kj} - X_{j+1} = 0, \forall j \quad (5)$$

$$X_{ik} \le Y_k G_k, \forall i, k \quad (6)$$

$$X_{kj} \le Y_j G_j, \forall j, k \quad (7)$$

$$\sum_k X_{kj} \le Y_j G_j, \forall j \quad (8)$$

$$\sum_i X_{ik} \le Y_k G_k, \forall k \quad (9)$$

$$\sum_i X_{ik} = p_k, \forall k \quad (10)$$

$$\sum_k X_{kj} = p_j, \forall j \quad (11)$$

$$p_j \ge y_j, \forall j \quad (12)$$

$$p_k \ge y_k, \forall k \quad (13)$$

$$Y_k, Y_j \in \{0,1\} \tag{14}$$

$$X_{ik,} X_{kj}, X_{j+1} \geq 0 \tag{15}$$

Objective function (1) minimizes transportation costs of transporting LIBs from end user zones to collection points, treatment facilities and landfill sites. Objective function (2) minimizes the risk for residents located along the transportation routes of vehicles transporting LIBs. Equitation (3) ensures that all LIBs quantities located at end user zones are transferred to collection points. Constraints (4) and (5) are flow conservation constraints, for collection point and treatment facility level respectively. Equitation (5) models the minimum disposal fraction from treatment point level. Constraints (6) to (9) are capacity and opening constraints, but since we are not determining locations of landfill sites, no opening constraints are used for this type of facility. Constraints (10) i (11) determines the quantities of LIBs transported to collection points and treatment facilities, respectively. While the constraints (12) and (13) enables that locations for collection points and treatment facilities aren't opened if some quantities of LIBs isn't allocated to them. Constraint set (14) enforce the binary restriction on the Y decision variables, while constraint set (15) requires the decision variable X to be continuous between zero and one.

3. NUMERICAL EXAMPLE

In this section, the proposed bi-objective model for collection points and treatment facilities locating for end-of-life lithium-ion batteries was tested on small scale illustrative example. The observed example consists of 335 end users (LIBs generators), 9 nodes which are simultaneously potential collection points and treatment facility locations, and one known location for landfill site. Input parameters for numerical example are presented in Table 1 (adopted and slightly modified from Subula et al. (2015)).

Table 1. Input parameters for numerical example

Parameters	**Values**
LIBs generation (units)	Uniform distribution (500,2500)
Unit transportation cost for LIBs (€/km unit)	0.8
Fixed cost of opening collection centers	100000
Fixed cost of opening treatment facilities ($)	300000
Capacity of collection points (units)	120000
Capacity of treatment facilities (units)	550000
α minimal disposal fraction of LIBs	0;0.3;0.5;1

Due to large number of end users zones, distances used for calculating transportation costs are not presented in this paper. In order to solve proposed bi-objective model a number of methods can be used. In this, paper relaxed lexicographical method was used that allows the decision maker to express importance of the objective functions (i.e. ranks them by relevance). In this paper, the objective function indices define their ranking so the most important is expressed as OF1, and OF2 is second in rank by the relevance. Problem was developed using Python 2.7 programming language and solved by CPLEX 12.6 software. Numerical results for α =(0, 0.3,0.5,1) are presented in Table 2.

Table 2. Numerical result for α =(0, 0.3,0.5,1)

	OF1 value	OF2 value	opened CPs	opened TS
α =0.5	5689740	25559139888	2,3,4,7,9	2,3,4,7
	6000000	22819969120	1,2,3,4,7	1,2,3,4,7
	7000000	14678084881	1,2,4,7,9	1,2,4,7,9
	8000000	13312505871	1,4,7,8,9	1,4,7,8,9
	9000000	13053803405	1,4,7,8,9	1,4,7,9
	10000000	12906755386	1,4,7,8,9	1,4,7,9
	11000000	12759707366	1,4,7,8,9	1,4,7,9
	12000000	12600683304	1,4,7,8,9	1,4,7
	13000000	12507079952	1,4,7,8,9	1,4,7
	14000000	12413476600	1,4,7,8,9	1,4,7
	15000000	12319873248	1,4,7,8,9	1,4,7
	16000000	12238040603	1,4,7,8,9	4,7
	17000000	12210270961	1,4,7,8,9	4,7
	18000000	12182501318	1,4,7,8,9	4,7
	19000000	12154731675	1,4,7,8,9	4,7
	20000000	12126962032	1,4,7,8,9	4,7
	21000000	12095550651	1,4,7,8,9	7
α =0.3	4276880	21911015758	1,2,3,4,7	1,2,3,4,7
	5000000	12854492870	1,2,4,7,9	1,2,4,7
	6000000	11496616210	1,4,7,8,9	1,4,7,9
	7000000	11413014975	1,4,7,8,9	1,4,7,9
	8000000	11329413739	1,4,7,8,9	1,4,7,9
	9000000	11245812504	1,4,7,8,9	1,4,7,9
	10000000	11153181644	1,4,7,8,9	1,4,7
	11000000	11099605647	1,4,7,8,9	1,4,7
	12000000	11046029650	1,4,7,8,9	1,4,7
	13000000	10992453654	1,4,7,8,9	1,4,7
	14000000	10935098729	1,4,7,8,9	4,7
	15000000	10918640213	1,4,7,8,9	4,7
	16000000	10902181697	1,4,7,8,9	4,7
	17000000	10885723182	1,4,7,8,9	4,7
	18000000	10869264666	1,4,7,8,9	4,7
	19000000	10852806150	1,4,7,8,9	4,7
	20000000	10844970038	1,4,7,8,9	7
α =0	9054514	34181131611	2,3,4,7,9	2,3,4,7
	10000000	29208474504	2,3,4,7,9	2,3,4,7
	11000000	24115588859	1,2,3,4,7	1,2,3,4,7
	12000000	19344159134	1,2,4,7,9	1,2,4,7,9
	13000000	18001485362	1,2,4,7,9	1,2,4,7,9
	14000000	17209005166	1,4,7,8,9	1,4,7,9
	15000000	16867675037	1,4,7,8,9	1,4,7,9
	16000000	16479504901	1,4,7,8,9	1,4,7
	17000000	16181284270	1,4,7,8,9	1,4,7
	18000000	15968387193	1,4,7,8,9	1,4,7
	19000000	15755490115	1,4,7,8,9	1,4,7
	20000000	15523945466	1,4,7,8,9	4,7
	21000000	15466636711	1,4,7,8,9	4,7
	22000000	15409327956	1,4,7,8,9	4,7
	23000000	15352019201	1,4,7,8,9	4,7
	24000000	15294710446	1,4,7,8,9	4,7
	25000000	15222002184	1,4,7,8,9	7
α =1	2128240	9190082238	1,3,4,6,7	1,3,4,6,7
	2200000	8969099119	1,4,7,8,9	1,8,9

In case when α=0.5, marginal solution for OF1 is y_k=(0,1,1,1,0,0,1,0,1) and y_j=(0,1,1,1,0,0,1,0,0) and objectives' values are OF1=5689740, OF2=25559139888. Marginal solution for OF2 is y_k=(1,0,0,1,0,0,1,1,1) and y_j=(0,0,0,0,0,0,1,0,0) and objectives' values are OF1=21000000€, OF2=12095550651 residents*kg. In case when α=0.3, marginal solution for OF1 is y_k=(1,1,1,1,0,0,1,0,0) and y_j=(1,1,1,1,0,0,1,0,0) and objectives' values are OF1 4276879.568€, OF2= 21911015758. In case when α=1, which represents the case when all collected LIBs units are sent to landfill site, marginal solution for OF1 is y_k=(0,1,1,1,0,0,1,0,1) and y_j=(0,1,1,1,0,0,1,0,0) and objectives' values are OF1= 9054514.351€, OF2= 34181131611. In case when α=0, which represents the case when all collected LIBs units are sent to transfer stations, marginal solution for OF1 is y_k=(1,0,1,1,0,1,1,0,0) and y_j=(1,0,1,1,0,1,1,0,0) and objectives' values are OF1= 2128240.322€, OF2= 9190082238. It is usual that the decision maker has preferences for certain objectives (e.g. costs), so one solving approach could be relaxed lexicographic method to support such preference expressed by their order. If the decision maker chooses in this model OF1 as preferable objective, then if for example he/she allows the total cost to increase for 5.45 % from the optimal OF1 (from 5689740 to 6000000€), OF2 could decrease for 10.72 % (from 25559139888to 22819969120) for α=0.5.

3. CONCLUSION

This paper presents a possible approach to define the optimal logistics network for end-of-life LIBs. The proposed model aims finding effective strategies for the return of discarded LIBs from end users to treatment facilities and landfill site, via collection points, with minimal costs. The second objective in the proposed model minimizes the risk associated with transport of end-of-life lithium-ion batteries for end users located along the routes of transportation vehicles. Although the results obtained give some answers related to the possibility of defining optimal locations of these facilities, in sense of indicating complexity and importance of the problem, numerous aspects of the problem are still without answer, and need future research. Future research could include aggregation concept to be applied for grouping end users to be analyzed as a LIBs generation sources, different approaches for problem solving, consideration of uncertainty in generated LIBs quantities, etc.

ACKNOWLEDGMENT

This paper was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia through the project TR 36006.

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A MIQP MODEL FOR SOLVING THE VEHICLE ROUTING PROBLEM WITH DRONES

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Abstract: *The presence of drones in everyday life expands on a daily basis. In the last couple of years, the usage of aerial drones (UAV-Unmanned Aerial Vehicles) in last-mile parcel delivery attracts more and more attention. Some companies (mainly in the USA and Australia) have already tested and applied the usage of drones in the parcel delivery. There are many papers describing a two-phase approach for routing the drone–ground vehicle tandem. Most of the previous work in this domain propose different heuristics, metaheuristics and optimization approaches for the transformation of a given truck route to a truck-drone route. Considering the simultaneous approach for solving the routing problem with drones, the literature is very scarce. The purpose of this paper is to present a novel MIQP (Mixed Integer Quadratic Programming) model of a simultaneous approach to solving the VRPDTW (Vehicle Routing Problem with Drones and Time Windows).*

Keywords*: MIQP, VRP, Unmanned Aerial Vehicles, Last-mile parcel delivery.*

1. INTRODUCTION

The usage of drones finds its place in many different spheres of everyday life: military purposes, surveillance, sports and recreation and of course logistics. The two main domains of drone application in logistics are distribution and warehousing. In warehousing, the drones are used for scanning purposes, while in the distribution the drones find their application in small parcel delivery. The application of drones in parcel delivery results in different kind of problems that must be solved: regulatory and safety problems, technical problems and the most interesting group - the tactical and operating problems (in this case, the routing problem). From 2015 and up to today, many articles and papers described various approaches for solving routing problems with drones. The purpose of this paper is to present a novel Mixed Integer Quadratic Programming (MIQP) model for solving the Vehicle Routing Problem with Drones and Time Windows (VRPDTW) with simultaneous optimization of both vehicle and drone operations. In the following sections of this paper we present a literature review on the topic of VRP with

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drones, problem formulation, the MIQP model, test instances with computational results and the concluding remarks.

2. LITERATURE REVIEW

The first papers proposing a solution to routing problem with drones appeared in 2015. Murray and Chu (2015) described a new subtype of the classical TSP (Traveling Salesman Problem) and named it FSTSP (Flying Sidekick Traveling Salesman Problem). In their paper, the authors propose a MILP model for the transformation of a given truck route to a truck-drone route. Later, in the same year, Agatz et al. (2015) proposed another MILP model for solving the so-called TSPD (Traveling Salesman Problem with Drones). These two papers were the pioneers of research in the area of solving routing problems with drones, so all other papers in the following years were related to the aforementioned research. In literature, there are many papers proposing different heuristics and metaheuristics for improving the approaches described in two aforementioned papers. Ponza (2016) showed that the application of SA (Simulated Annealing) can lead to much greater savings of the traveling time, compared to the original FSTSP. Ponza also proved that different technical characteristics of drones affect the setup of models for solving the routing problem with drones. Marinelli et al. (2017) describe an interesting approach for improving the initial TSPD solution, called "en-route" approach. All of the previous work assumed that the drone can leave/join the truck only at the customer nodes that are visited by the truck. The idea of "en-route" approach is to examine the effects of the concept where the drones could be launched from any point along an arc that the truck is traversing. Also, drones could join the truck again at any point along an arc that the truck is traversing. The authors proposed a heuristic for the "en-route" approach and proved that this approach could lead to significant savings in traveling time, due to the reduction of the total waiting time. The possible problem with this approach comes from the fact that sometimes the truck is not allowed to stop along the arcs. Savurhan and Karakaya (2015) developed a genetic algorithm for solving the TSPD. Luo et al. (2017) described a two-echelon approach for the TSPD, and they named it 2E-GU-RP (2 Echelon – Ground Vehicle and Unmanned Aerial Vehicle – Routing Problem). In the 2E-GU-RP the truck serves as a mobile warehouse, while all the nodes are served by the drones. When the truck stops at a certain location, all the nodes (that are in the flight range) are being served by drones. This approach could have a practical application in scenarios in which many of the customer nodes could not be visited by the ground vehicle. Ferrandez et al. (2016) compared the effects of truck-only, truck-drone tandem and drone-only (2E-GU-RP) parcel delivery.

Although Murray and Chu (2015) and Agatz et al. (2015) propose a one-phase approach for solving a one-vehicle routing problem with drones, to the best of our knowledge there is no previous work considering the one-phase approach for solving a routing problem with multiple vehicles and drones. Accordingly, the goal of this paper is to present a novel MIQP model of a systematic approach for solving the VRPDTW. The following chapters will describe and analyze the application of the proposed MIQP model for solving the VRPDTW.

3. PROBLEM FORMULATION

The goal of VRPDTW is finding the joint vehicles and drones routing solution with minimal cost for delivery from a single depot to a given set of customer locations with defined time windows, while some of the customer locations could be visited and served by a drone (while all locations can be visited by vehicles). In this paper, a heterogeneous fleet of vehicles is considered, which means that some of the vehicles contain a drone and some of them do not. The drone can depart/join the ground vehicle only at a customer node, while every drone is bound to its ground vehicle (it is not allowed for the ground vehicles to exchange drones). The proposed approach is cost-based, so the goal is to construct the least expensive solution, while the costs consist of traveling costs and labour costs.

4. MATHEMATICAL FORMULATION OF THE MIQP

The MIQP formulation in this paper is a derivate of the three-index MILP formulation by Fisher and Jaikumar (1978) given for solving the classical VRP. Let *V* be the set of all available ground vehicles, while V_k is the set of ordinary vehicles and V_d is the set of vehicles with drones ($V_k \cup V_d = V$). Let *I* be the set of all customer nodes, while *K* is the set of nodes that could potentially be visited by a drone $(K \subset I)$. The binary variable X_{ij}^{v} equals 1 if the vehicle *v* is traversing the arc *i-j*, and equals 0 if otherwise. The second binary variable X_{ikj}^{v} equals 1 if the vehicle *v* traverses the arc *i-j*, while the vehicle's drone traverses along the *i-k-j* section*,* otherwise, it equals 0. For each *i,j* pair there is a continuous variable C_{ij} that represents the distance between *i* and *j,* while C_{ikj} represents the distance *i-k-j*. Let T_v be a continuous variable that represents the route completion time for vehicle *v*. Analogously to the C_{ij} variables, t_{ij} variables represent the traveling time between each *i,j* pair of nodes, while t_i is an auxiliary variable that represents the moment when the node *i* is visited by a vehicle. The variable t_{ikj} represents the time needed for the drone to traverse the *i-k-j* section. Also, let Y_i^{v} be 1 if the node *i* is visited by vehicle *v,* 0 if otherwise. The objective function (1) aims to minimize the overall cost, while it distinguishes between the labour costs and traveling costs. Labour cost is calculated as a product of labour cost per minute – α, and the sum of all route completion times (for every vehicle). The traveling costs vary according to the vehicle type: β represents the distance unit cost for classical vehicles, η represents the distance unit cost of drone carrying vehicles, while ω represents the distance unit cost of drones. All the aforementioned results in the following MIQP formulation:

$$\min \sum_{v\in V} \alpha \cdot T_v + \sum_{i\in I}\sum_{j\in I}\sum_{v\in V_k} \beta \cdot C_{ij} \cdot X_{ij}^{v} + \sum_{i\in I}\sum_{j\in I}\sum_{v\in V_d} \eta \cdot C_{ij} \cdot X_{ij}^{v} + \sum_{i\in I}\sum_{j\in I}\sum_{k\in K}\sum_{v\in V_d} \left(\eta \cdot C_{ij} + \omega \cdot C_{ikj}\right) X_{ikj}^{v} \tag{1}$$

such that:

$$\sum_{v=1}^{m} Y_i^{v} = \begin{Bmatrix} 1, & \forall i \in I \backslash 0 \\ m, & i=0 \end{Bmatrix} \tag{2}$$

$$\sum_{i\in I}\sum_{j\in I}\sum_{k\in K} t_{ikj}\cdot X_{ikj}^{v} \le T_{\max}^{d} \qquad i\ne j\ne k,\ \forall v\in m \tag{3}$$

$$t_0 = 0 \tag{4}$$

$$t_i + t_{i0} \le T_{\max}^{kam} \qquad \forall i\in I \tag{5}$$

$$t_j \ge t_i + T_{opsluge} + t_{ij} - \left(1-\left(\sum_{v=1}^{m} X_{ij}^{v} + \sum_{v\in Vd}\sum_{k\in K} X_{ikj}^{v}\right)\right)\cdot T_{\max}^{kam} \qquad \forall i,j\in I,\ i\ne j \tag{6}$$

$$t_j \le t_i + T_{opsluge} + t_{ij} + \left(1-\left(\sum_{v=1}^{m} X_{ij}^{v} + \sum_{v\in Vd}\sum_{k\in K} X_{ikj}^{v}\right)\right)\cdot T_{\max}^{kam} \qquad \forall i,j\in I,\ i\ne j \tag{7}$$

$$t_{ij} \ge \sum_{v\in V} X_{ij}^{v}\cdot\frac{C_{ij}}{V_{kam}} \qquad \forall i,j\in I,\ i\ne j \tag{8}$$

$$t_{ij} \ge \sum_{v\in Vd} X_{ikj}^{v}\cdot\frac{C_{ij}}{V_{kam}} \qquad \forall i,j\in I,\ \forall k\in K,\ i\ne j\ne k \tag{9}$$

$$t_{ij} \ge \sum_{v\in Vd} X_{ikj}^{v}\cdot\frac{C_{ikj}}{V_{drona}} \qquad \forall i,j\in I,\ \forall k\in K,\ i\ne j\ne k \tag{10}$$

$$a_i \le t_i \le b_i \qquad \forall i\in I \tag{11}$$

$$Y_i^{v} = \left\{\begin{array}{l} \sum_{j\in I} X_{ij}^{v} + \sum_{j\in I}\sum_{k\in K} X_{ikj}^{v}, v\in Vd \\ \sum_{j\in I} X_{ij}^{v}, v\notin Vd \end{array}\right\} \qquad \forall i\in I,\ \forall \mathrm{v}\in \mathrm{m},\ \mathrm{i}\ne \mathrm{j}\ne \mathrm{k} \tag{12}$$

$$Y_i^{v} = \left\{\begin{array}{l} \sum_{j\in I} X_{ji}^{v} + \sum_{j\in I}\sum_{k\in K} X_{jki}^{v}, v\in Vd \\ \sum_{j\in I} X_{ji}^{v}, v\notin Vd \end{array}\right\} \qquad \forall i\in I,\ \forall \mathrm{v}\in \mathrm{m},\ \mathrm{i}\ne \mathrm{j}\ne \mathrm{k} \tag{13}$$

$$T_v \ge \left\{\begin{array}{l} (t_{i0}+t_i)\cdot X_{i0}^{v},\ \forall \mathrm{v}\in \mathrm{V}_k \\ (t_{i0}+t_i)\cdot (X_{i0}^{v}+\sum_{k\in K} X_{ik0}^{v}),\ \forall \mathrm{v}\in \mathrm{V}_d \end{array}\right\} \qquad \forall i\in I\setminus 0,\ \mathrm{i}\ne \mathrm{k} \tag{14}$$

$$W_d^{ikj} \ge X_{ikj}\cdot\left(\frac{C_{ij}}{V_{kamiona}} - \frac{C_{ikj}}{V_{drona}}\right) \qquad \forall i,j\in I,\ \forall k\in K,\ i\ne j\ne k \tag{15}$$

$$W_d^{ikj} \ge 0 \qquad \forall i,j\in I,\ \forall k\in K,\ i\ne j\ne k \tag{16}$$

$$W_v^{ikj} \ge X_{ikj}\cdot\left(\frac{C_{ikj}}{V_{drona}} - \frac{C_{ij}}{V_{kamiona}}\right) \qquad \forall i,j\in I,\ \forall k\in K,\ i\ne j\ne k \tag{17}$$

$$W_v^{ikj} \ge 0 \qquad \forall i,j\in I,\ \forall k\in K,\ i\ne j\ne k \tag{18}$$

Constraint (2) ensures that every node must be visited by a vehicle exactly once, while the depot must be visited by all vehicles *V*. Constraint (3) ensures that the drone flight would not exceed the maximum drone flying time $T_d^{\max}$. Constraint (4) sets the depot departure time, and sets the beginning moment of every vehicle route (0 s), while the constraint (5) ensures that every vehicle has enough time to return to the depot in the limits of the allowed maximum route duration time ($T_{kam}^{\max}$). Constraints (6) and (7) define the visiting moment of every node, and together with the constraint (5) eliminate all sub-tours. The variable $T_{opsluge}$ represents the time needed for serving the customer upon the arrival to the customers' location. Constraints (8), (9) and (10) set the values for the time needed for traveling between two nodes, whether the *i-j* distance is travelled only by a ground vehicle, or the distance *i-j* is traversed by a ground vehicle, while the drone traverses the *i-k-j* distance. In the case of drone assistance, the time t_{ikj} will be equal to the greater value of the time needed for the truck to traverse the distance *i-j*, and the time that it takes for the drone to traverse *i-k-j*. Constraint (11) ensures that no time-window is violated, while (12) and (13) ensure that every node has exactly one inbound and one outbound arc. Equation (14) sets the corresponding values to the variables that represent the time needed for a vehicle to complete its tour. Constraints (15), (16), (17) and (18) calculate the drone and truck waiting times for every *i-k-j* arc that is served by a truck-drone tandem.

5. INSTANCE GENERATION AND MIQP MODEL SETUP

This section will explain the instances, input parameters' values and MIQP model setup. There are several types of instances and they are shown in Table 1. Every instance consists of 10 nodes and a depot. There are two variants of depot location: in the first variant the depot is located at [0,0], and in the second variant the depot is located in the center of the defined area. There are two instance area sizes: 30 km x30 km and 60 km x60 km. Also, two variants of node structures are considered: the first variant consists of nodes where half of them could be visited by the drone, and in the second variant, all nodes could be visited by the drone. All nodes are randomly distributed in the defined area, with randomly generated time-windows within the boundary time-windows range. There are three considered types of time-windows range: 60 min, 120 min and 480 min. Regarding the MIQP model input parameters, the labour costs value is set to 0.05 €/min, while the distance unit cost values for classical vehicles, drone carrying vehicles and drones are set to 1.0, 1.5 and 0.2 €/min respectively. $T_{opsluge}$ is set to be 10 minutes. The speed of the ground vehicles is set to be 40 km/h, while the speed of drones is set to 60 km/h. The maximum allowed route duration time per vehicle is set to be 8 hours, while the maximum allowed CPU for solving an instance is set to be 30 min.

6. RESULTS ANALYSIS

In this chapter, the result analysis of the MIQP model application will be presented. The following output parameters and results will be analyzed: the average objective function value, the average CPU, the average distance travelled, the average vehicle traveling time, the average vehicle waiting time and the average number of used vehicles. All the aforementioned parameters will be analyzed and compared from the aspect of different vehicle types and the maximum drone flight range. The model solved all instance with optimality within given CPU time restriction, except for instance types 4 and 16 when the maximum drone flight time is set up to be 60 minutes.

Table 1. Instance types

Instance type	Depot location	Area dimensions (km x km)	Percentage of drone nodes	Time windows range (min)
Type 1	[0,0]	30x30	50%	120
Type 2	[0,0]	30x30	100%	120
Type 3	[0,0]	30x30	50%	480
Type 4	[0,0]	30x30	100%	480
Type 5	[0,0]	30x30	50%	60
Type 6	[0,0]	30x30	100%	60
Type 7	[0,0]	60x60	50%	120
Type 8	[0,0]	60x60	100%	120
Type 9	[0,0]	60x60	50%	480
Type 10	[0,0]	60x60	100%	480
Type 11	[0,0]	60x60	50%	60
Type 12	[0,0]	60x60	100%	60
Type 13	center	30x30	50%	120
Type 14	center	30x30	100%	120
Type 15	center	30x30	50%	480
Type 16	center	30x30	100%	480
Type 17	center	30x30	50%	60
Type 18	center	30x30	100%	60
Type 19	center	60x60	50%	120
Type 20	center	60x60	100%	120
Type 21	center	60x60	50%	480
Type 22	center	60x60	100%	480
Type 23	center	60x60	50%	60
Type 24	center	60x60	100%	60

From Table 2 it can be noticed that the average objective function had a lower value in the model variant where T_d^{max} =60 min. However, a better objective function value lead to greater CPU times. The conclusion that can be made is that the cost of the truck-drone parcel distribution decreases with the improvement of the technical characteristics of the drone (in this case, the drone flight range). The average objective function value for all instances and both model setups is 217.5 €, while the average CPU is 100 s. Comparing the two T_d^{max} input values, the MIQP model gave better cost savings when all the nodes were available for the drone to visit with T_d^{max} =60 min. The average cost savings of T_d^{max} being 60 instead of 30 min is 7.23%, while the average increase of CPU needed for solving the instances is 277 s. The only instance type where the model with T_d^{max} = 30 min outperforms the 60 min version is type 4. The reason this occurred is that the model could not solve some instances to optimality within the given CPU time restriction when T_d^{max} was set to be 60 min.

The second parameter that will be analyzed is the average distance travelled by a vehicle type. The average values per different instance types are shown in Figures 1 and 2. The average distance travelled for the case T_d^{max} = 30 min is 151 km for the classic truck, 20 km for the drone carrying truck and 26 km for the drone. The average distance travelled for the case T_d^{max} = 60 min is 92 km for the classic truck, 45 km for the drone carrying truck and 81 km for the drone. The average reduction of classic truck route length is 39%, and the average increase of drone carrying truck and drone routes are 122% and 212% respectively when changing the value of T_d^{max} from 30 to 60 min.

Table 2. Average objective function value and average CPU by instance for T_d^{max} of 30 and 60 min

Instance type	T_d^{max} = 30 min Avg. objective function value (€)	T_d^{max} = 30 min Avg. CPU time (s)	T_d^{max} = 60 min Avg. objective function value (€)	T_d^{max} = 60 min Average CPU time (s)	Difference of 60 min from 30 min T_d^{max} solutions Obj. func. (%)	Difference of 60 min from 30 min T_d^{max} solutions CPU time (%)
Type 1	167.52	12.26	165.64	37.67	-1.12	207.26
Type 2	156.20	28.66	149.42	312.27	-4.34	989.57
Type 3	119.44	183.53	119.44	388.15	0.00	111.49
Type 4	119.44	340.74	120.39*	1262.60	0.80	270.55
Type 5	207.28	2.03	199.65	5.69	-3.68	180.30
Type 6	170.40	3.91	158.95	24.33	-6.72	522.25
Type 7	375.29	4.51	361.15	8.81	-3.77	95.34
Type 8	371.52	5.77	311.15	20.01	-16.25	246.79
Type 9	233.88	34.12	233.88	113.11	0.00	231.51
Type 10	233.88	60.87	233.88	259.66	0.00	326.58
Type 11	418.05	0.88	404.90	1.82	-3.15	106.82
Type 12	411.38	1.30	355.98	4.16	-13.47	220.00
Type 13	148.78	12.06	146.18	35.86	-1.75	197.35
Type 14	131.25	67.15	117.65	131.67	-10.36	96.08
Type 15	107.84	34.42	106.27	124.98	-1.46	263.10
Type 16	105.20	148.20	98.96*	848.24	-5.93	472.36
Type 17	161.90	2.66	157.91	9.18	-2.46	245.11
Type 18	135.72	6.52	120.02	25.69	-11.57	294.02
Type 19	291.90	2.28	271.33	6.80	-7.05	198.25
Type 20	288.60	4.57	237.75	19.58	-17.62	328.45
Type 21	215.61	10.22	210.92	44.03	-2.18	330.82
Type 22	215.61	40.00	206.25	118.99	-4.34	197.48
Type 23	318.29	0.88	293.72	1.46	-7.72	65.91
Type 24	313.15	1.43	244.75	2.99	-21.84	109.09
Total avg.	225.76	42.04	209.42	158.66	-7.23	277.39

**-some MIQP solutions were not solved to optimality in available computational time*

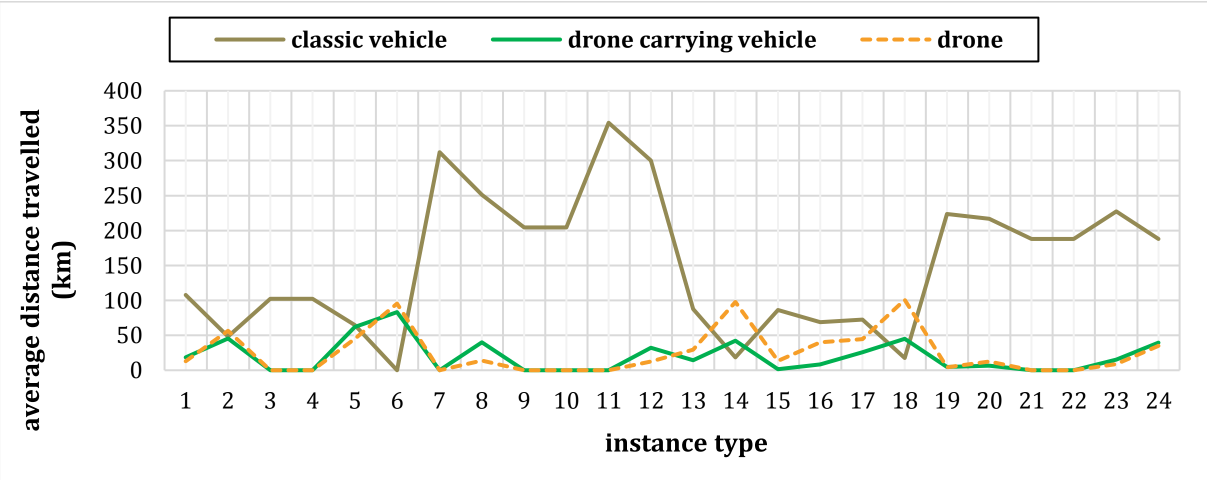

Figure 1. Average distance travelled by vehicle type, T_d^{max} = 30 min

The vehicle route lengths were drastically reduced with the increase of the maximum allowed drone flight time. As expected, the intervention of drone is greater in the instances where the drone is allowed to visit all of the nodes. In instance types 3, 4, 9 and 10, for both T_d^{max} values, all the nodes were visited by the classic truck, and no drone was used for parcel delivery in these instance types. The classic vehicle was never used in instance type 6. So, the conclusion is that the traveling distance and the usage of different vehicle types is strongly dependent on the instance structure, as well as the characteristics of the drone.

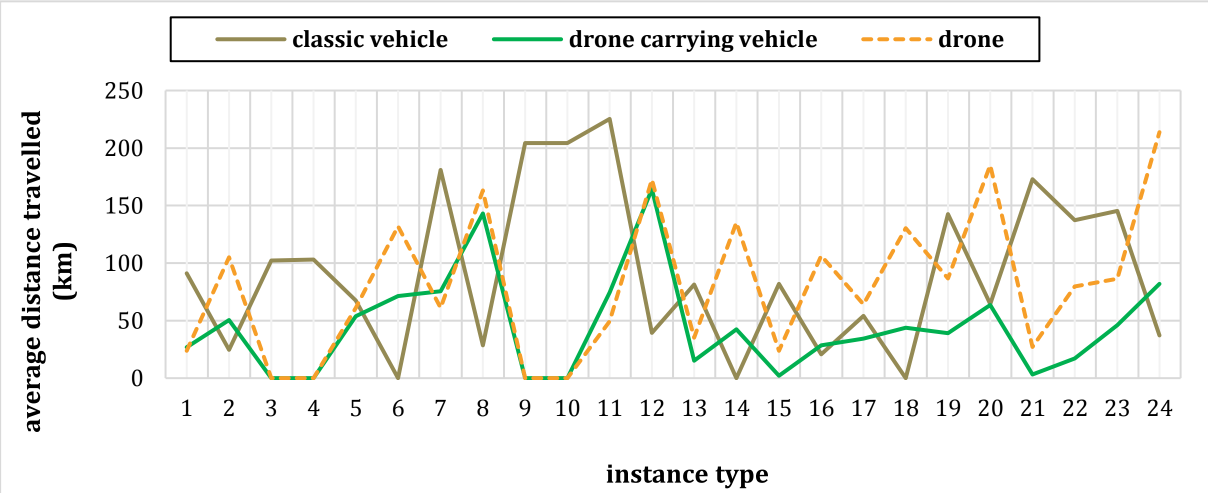

Figure 2. Average distance travelled by vehicle type, T_d^{max} = 60 min

Figures 3 and 4 show that the average time travelled per vehicle type varies for different instance types. All the results of traveling time are related to the results of the distance travelled by each vehicle type. Considering the waiting times, the average waiting time of the truck was 11.15 min (with T_d^{max} = 30 min) and 38.72 min (with T_d^{max} =60 min. The drone waiting time had always a lesser value than the truck waiting time, except on the instance type 12 and T_d^{max} = 60 min.

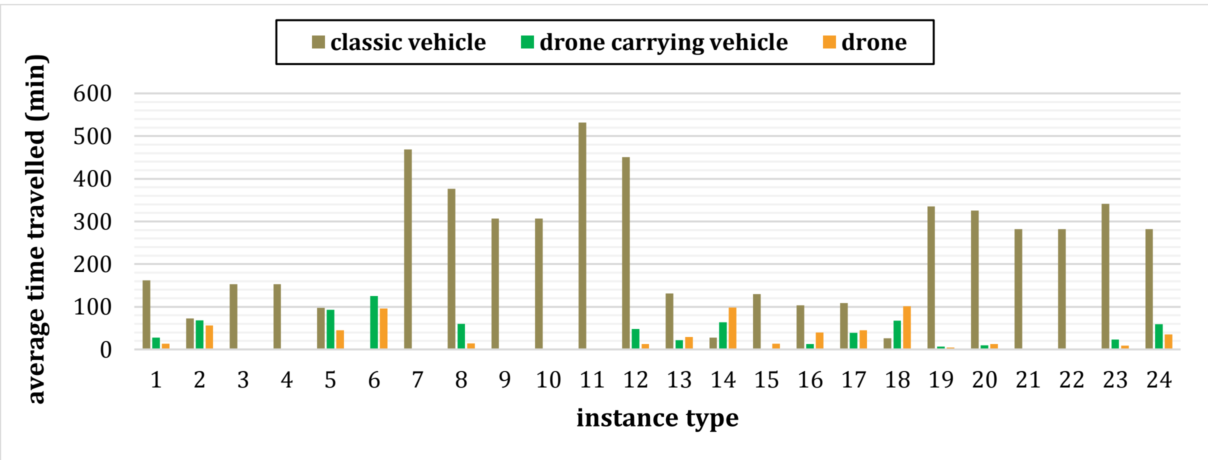

Figure 3. Average time travelled by vehicle type, T_d^{max} = 30 min

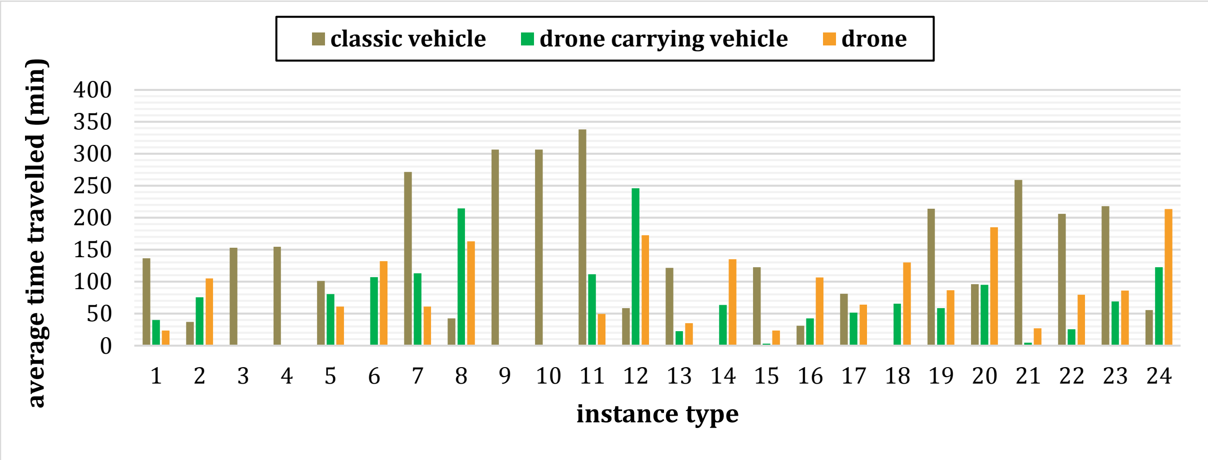

Figure 4. Average time travelled by vehicle type, $T_d^{\max}$ = 60 min

Considering the average number of used vehicles, the increase of the allowed drone flight time results in a more frequent usage of drone-carrying trucks in parcel delivery. The average number of used vehicles (both classic and ones carrying drone) when $T_d^{\max}$ = 30 min is 1.5, while the average number of used vehicles when $T_d^{\max}$ = 60 min was 1.4. Based on this result, we can conclude that the usage of drones with better technical characteristics could lead to a reduction in the number of ground vehicles needed for distribution.

Different route structures for the same instance, with a different number of drone nodes, and different $T_d^{\max}$ are shown in Figure 5. It is obvious that the route structures are strongly dependent on the allowed drone flight time and the number of locations that could be visited by the drone.

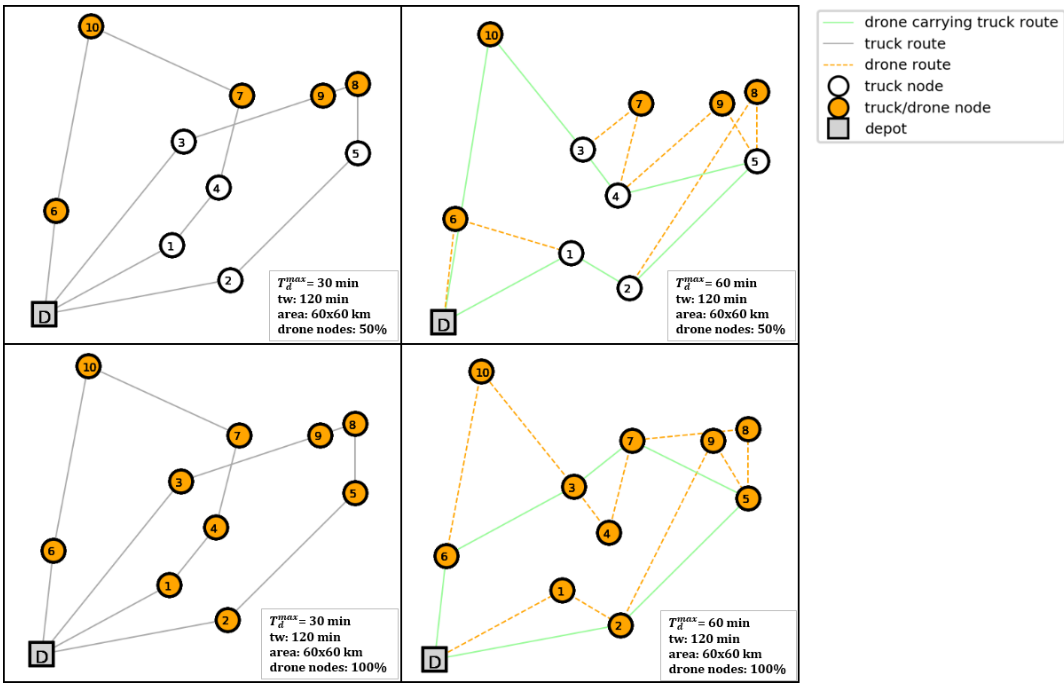

Figure 5. Different route structures per some instance types

7. CONCLUSION

In this paper, a novel MIQP model for solving the VRPDTW in a systematic manner is presented. The model was formulated to solve various types of costs in a tandem vehicle-drone parcel delivery, with the goal of minimizing the distribution cost related to travelled distance and working time. The model was used to solve various types of instances. The application results have shown that a significant cost saving could be achieved with the intervention of drones in parcel delivery. Further research could go in several directions. The first direction could be exploring the effects of the approach where the ground vehicles could exchange drones so that no drone is bound to a particular truck. The other research directions could focus on how the improvement of drone technical characteristics could affect the distribution and logistics in general. Also, a development of a heuristic approach to solve larger scale instances that are closer to real-life dimensions is one of the interesting research possibilities.

ACKNOWLEDGMENT

This work was supported by the Ministry of Education, Science and Technical development of the Government of the Republic of Serbia through the project TR36006, for the period 2011-2019.

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FRAMEWORK FOR SIMULATION ANALYSIS OF PRIORITY QUEUES STRATEGIES IN DETERIORATING GOODS SUPPLY

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Abstract: The Queuing theory has been considered as one of the most important methods with very wide application in making different improvements of the system performances, which are very often related to decreasing waiting times in queues. In order to reduce waiting time, many different techniques have been studied while the priority queuing models appear to be the most popular. Waiting times are of particular importance in case of deteriorating goods which lose its quality during the time, decreasing its economic value. Therefore, in this paper we propose concept of a simulation model which can analyse effects of priority queues strategies, on waiting times in deteriorating goods supply. The analysis is based on simulation model implemented in ARENA 15.1. Simulation experiments were realized on numerical examples of sugar beet supply.

Keywords*: Discrete event simulation, Priority queues, Deteriorating goods supply*

1. INTRODUCTION

As it is well known, queues are part of our everyday experience and exists in different real world systems and situations as a consequence of limited available resources. Examples are numerous and include telephone calls, ticket counters, vehicles requiring loading dock, aircrafts requiring gates or permission to take off or land, patients requiring attention by a doctor, etc. For improving the system performances and making it more efficient, which usually means lesser waiting time in queue, different queuing theory methods are available. The Queuing theory was introduced by Erlang (1909) more than hundred years ago. Since than it has been considered as one of the most important methods with very wide application which can give the answers to the questions related to design of different real systems. The main questions in queuing systems design are related to balance between level of service to customers and economy. Lesser number of

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customers waiting in queue and shorter waiting times mean more servers which is more costly, and vice versa. Waiting in queue causes different negative effects. Thus, waiting of emergency vehicle in traffic jam, or for green light, may have severe consequences to a patient in the car; trucking company charges detention fees when has to wait until the loading/unloading of a shipment; waiting of goods which lose its quality during the time (deteriorating goods), decreases its economic value. Furthermore, in healthcare systems the condition of the patients may deteriorate while they wait (Haviv, Ravner, 2016).

In order to reduce waiting time, many different techniques have been studied by researchers, where classical priority queuing models appear to be the most popular approach in such a system (Li, 2015). Classical, or absolute priority queuing model is first studied by Cobham (1954). In this model a customer of a given class is selected if only customers of higher priority classes are not waiting. Since then, different priority queuing models, like time dependent priority queues (Kleinrock, Finkelstein, 1967), accumulating priority queues (Haviv, Ravner, 2016) have been analysed. In parallel with widening of priority queues application areas, research effort has been also directed to developing algorithms for priority queue implementation in simulation software as a typical tool for queuing system analysis, beside analytical methods with limited practical applications.

Here, we use simulation to analyse effects of introducing different priority queues strategies in deteriorating goods supply. The idea is to model the supply system in which goods lose its quality during the supply process with multiple vehicle tours realization. Each tour includes loading of goods at storage locations, transportation from the locations to processing plant, sampling goods to determine its quality, weighing and unloading of goods at processing plant, as well as empty vehicle trip realization. The simulation model is implemented in ARENA 15.1, while the simulation experiments were realized on numerical examples based on sugar beet supply process, since the sugar content in harvested beet deteriorates throughout the time.

While the simulation analysis of sugar cane supply chains, particularly related to the trucks waiting times in various queues, is of particular interest and has been the subject of numerous researches, sugar beet supply is not in focus. Iannoni and Morabito, (2006) simulated three scenarios of sugar cane supply, related to changes in truck's fleet structure, and analyzed effects on waiting times and unloading capacity. Barnes et al. (1998) and Hansen et al. (2002) used simulation to study methods of reducing harvest–to–crush delays in the sugar industry. Diaz and Perez (2000) applied simulation to gain insights into the relations between various processes and the presence of bottlenecks in supply chain operations. However, there is no papers analysing effects of priority queues strategies management on deterioration level of raw materials supplied, which is novelty proposed in this research.

The remaining part of the paper is organised as follows: Section 2 defines the problem, while the concept and the structure of the simulation model is presented in Section 3. Characteristics of the supply system being simulated, together with results of simulation experiments are presented and discussed in Section 4. Finally, main conclusions are highlighted in Section 5.

2. THE PROBLEM STATEMENT

Different logistics supply systems manage goods that lose its quality during the time. Typical example is deteriorating goods in agro industries, where supply from harvesting to processing plant causes decreasing its economic value. Iannoni and Morabito (2006) mentioned orange, sugarcane and wood industries as the examples. Sugar beet, which is the main plant in European, as well as in Serbian sugar production, also belongs to deteriorating goods since the sugar content in beetroot, i.e. digestion, decreases during the time. Loss in digestion is expressed in the percentage (%) of roots' weight, and varies depending on weather conditions and characteristics of the beet. According to Pan et al. (2015), sugar content in beet on temperature of 4°C is approximately normally distributed with mean value of 20.43% and standard deviation of 1.48%. Under lower temperatures, sugar loss is 100-200 gr per ton of beet daily, but on higher temperatures, near 30°C, it can reach 2kg per ton of beet daily (Asadi, 2007).

Decreasing of sugar content is very important because usual campaign of collecting harvested beet lasts 3-6 days, while processing of beet which contains less than 14% of sugar is not economical. Based on Asadi (2007), functional relation between the sugar loss and time can be expressed by equation (1).

$$\rho_s = \rho_s^0 (1-\beta)^t \tag{1}$$

where:

- ρ_s the amount of sucrose in harvested beet stored on the storage pile s, after the time t;
- ρ_s^0 the initial amount of sucrose in harvested beet stored on the storage pile s in t=0;
- β the loss in sucrose content per time unit;
- t the time elapsed after storing the beet.

During the campaign about 100 vehicles make more than 200 tours in average every day, for a daily sugar mill capacity of 7000 tons. Transport demand is extremely high because sugar beet should be immediately, or as soon as possible, delivered from the fields to sugar mills. For such a system, where sugar beet lose sucrose content during the time, managing the supply chain from the piles where beet is stored after harvesting to the beet processing in sugar mill, represents important opportunity to increase efficiency of the sugar production process. Sugar beet supply chain includes following main phases (Figure 1): loading of beet at storage piles, transportation from storage locations to processing plant, sampling goods to determine its quality, weighing and then unloading of goods at processing plant - mill, and return of empty vehicle to storage piles where it starts a new tour.

Each operation requires certain time for its realization, but additionally, because of congestion, limited capacities of available resources and stochasticity of processes in supply chain, vehicles spend in queues a certain time, waiting for a service. More detailed representation of the sugar beet supply chain phases, processes and average times needed for its realization can be found in the paper of Žitňák and Korenko (2011).

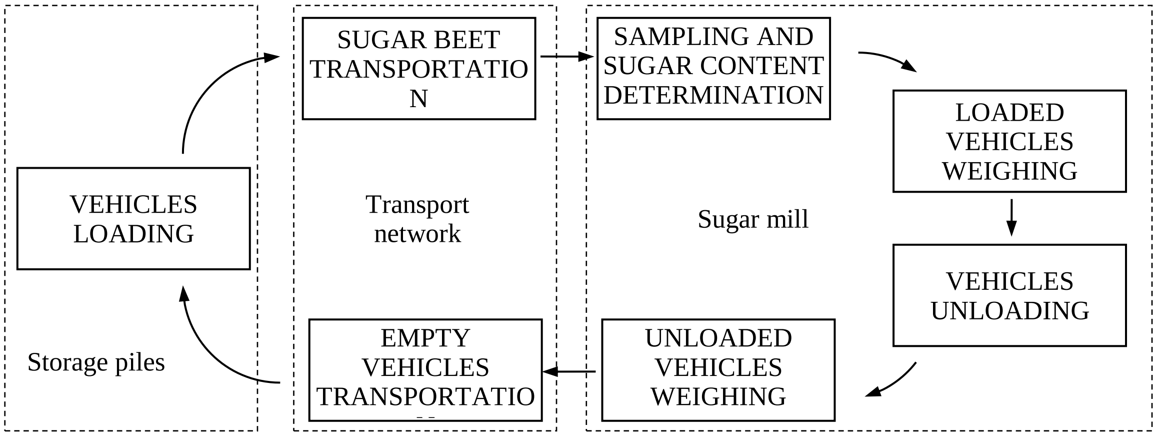

Figure 1. The main phases in sugar beet supply chain

Some of supply chain processes' realization times cannot be directly controlled, like supply vehicles travel times, while the other depend on resources' capacity. On the other hand, waiting times in different queues are controllable to some extent, even without changing resources capacities. Loading vehicles at storage piles and vehicles unloading in a mill are processes of that type. The most important process regarding waiting times is vehicles unloading in a mill. It is why Iannoni and Morabito (2006) correctly stated that the truck waiting times in various queues of the reception area are of special concern, particularly asserting the case of deteriorating goods.

In order to decrease quality deterioration, which is here related to the sugar loss minimization, we analyse the idea of dynamically changing the priority of vehicles which arrive in mill and wait in a queue to be unloaded. Instead of using FIFO service principle, we analyse priority based service strategy. Priority is based on the general principle "*larger sugar content - higher unloading priority*". This general principle is implemented through defining measure *CurrSugCont* whose value is then used as priority attribute assigned to each vehicle entering mill's unloading queues.

CurrSugCont Denotes estimated current sugar content in a beet. It is assumed that the amount of sucrose in the moment when harvested beet is stored on a source storage pile is known (*SugOnPile*). Based on that, knowing time passed from the moment when beet is stored, by using eq. (1) it is possible to estimate current sugar content for each vehicle tour, every time when vehicle arrives in a queue.

In order to perform analysis of possible effects of dynamically changing the service priority of vehicles waiting in queue, ARENA Queue option *Highest attribute value* is used for simulation model. This option gives service priority to the entity in queue (loaded vehicle) with the highest value of the certain attribute, which here corresponds to the values of attributes *CurrSugCont*.

3. SIMULATION MODEL

A simulation can be understood as imitation of a real world system or situation represented by computer model. It belongs to a class of descriptive models which are used to describe or analyse behaviour of the system being simulated. It provides to analyst an opportunity of making experiments on the model, instead on the real system. It has very wide application in analysis of effects which results from modification of different policies and strategies. This feature of simulation modelling approach is utilized in this research with the idea of analysing the effects of dynamically changing the service priority of vehicles waiting in mill's queues, based on the idea presented in the Figure 2.

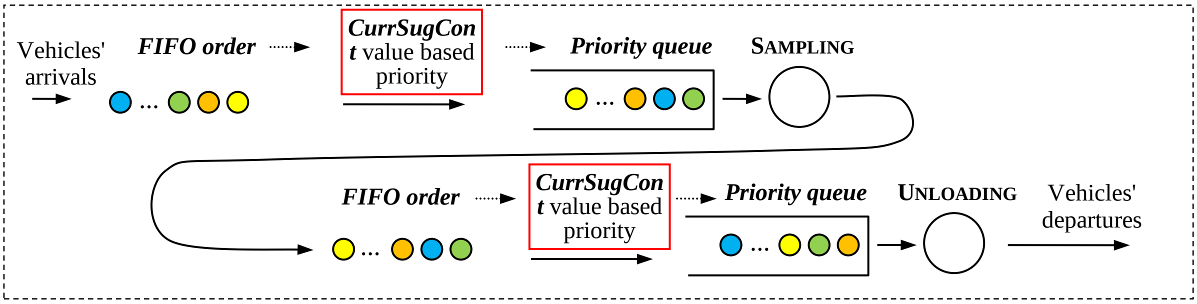

Figure 2. Dynamic change of service priority of vehicles waiting in the mill's queues

The simulation model of the sugar beet supply chain conceptually follows the processes and activities shown in Figure 1. The simulation model entities are trucks that upon entering the system make sugar beet collection tours until all beet is transferred from storage piles to the mill. Each tour includes vehicle loading at storage pile, movement of loaded trucks transporting beet to sugar mill, sampling of loaded vehicles to estimate sugar content, weighing vehicles, before and after unloading, vehicles unloading and then movement of empty vehicles to a sugar pile. It means that the sugar beet supply chain is considered as closed system. The simulation model has been developed in ARENA 15.1, while its simplified version which corresponds to a beet supply chain based on one storage pile is shown in Figure 3.

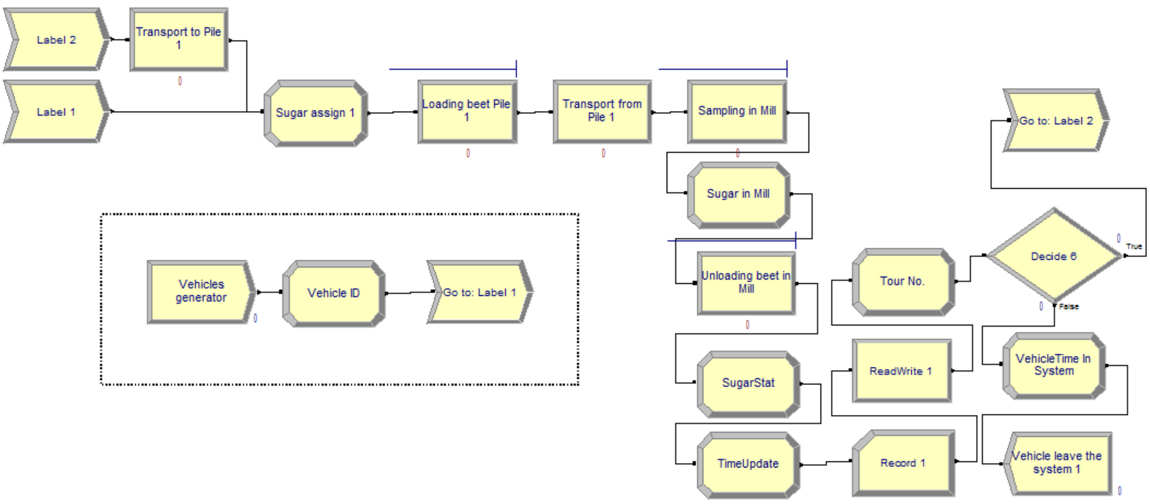

Figure 3. Simplified simulation model developed in ARENA based on one storage pile

Fleet of vehicles is generated prior the beginning of supply process. Each vehicle has been assigned its own ID. First tour of all vehicles starts from storage pile, not from the mill, where vehicle entity is assigned *SugOnPile* and current time (*CollTime*) attribute values. Sugar beet loading is realized by resource of ARENA process using FIFO service principle. Transport times are considered as ARENA processes of *Delay* type. After a vehicle entity enters the mill, it is assigned *CurrSugCont* attribute value, calculated by eq. (1). The servicing order is dynamically changed before the vehicle enters SAMPLING process. After sampling, vehicles enter mill's weighing and unloading queues, considered here as UNLOADING process. Unloading service order again depends on the priority, based on the new attribute value *CurrSugCont*, calculated by eq. (1). After the vehicle entity releases mill's processes model collects statistics and depending on the number of tours realized, entity is disposed or directed to the next storage pile according to the predefined schedule.

The model runs using FIFO, and defined prioritization strategy based service order with the idea of comparing effects that priority queue application strategy has on sugar loss.

4. SIMULATION EXPERIMENTS AND RESULTS

Data used in simulation experiments are based on an arbitrary mill with daily processing capacity of 6250 and 12500 tons which corresponds to realization of a 250 and 500 supply tours respectively, using vehicles of 25 tons capacity. Those processing capacities are slightly lower, and little higher than a typical mill which usually has capacity of 7000 tons daily, but give an opportunity for analyzing effects of priority queues strategy application. Mill supply area includes five storage piles (1,2,3,4,5), with the distances of 15, 12, 38, 39 and 59 kilometers from the mill, respectively. Average sugar content (%) on piles at the beginning of the supply process is assumed to be normally distributed with the mean value of 20.43% and standard deviation of 1.48%, accordingly to findings of Pan et al. (2015). Particular values of the sugar content for all piles obtained by simulation (*SugarOnStart*) are following: 18.73, 21.32, 19.41, 22.69, 21.38, for storage piles 1,2,3,4 and 5 respectively. As the sugar content in beet deteriorates in time, current content is estimated by simulation. It is assumed that deteriorated sugar content is also normally distributed with mean value decreased by extent calculated by eq.(1), and the same variation coefficient of 0.07.

Vehicles' schedule which defines visiting order of storage piles is randomly generated, and has a form given in Table 1. The vehicles' schedule is based on the concept of equal usage of vehicles, each performing ten tours. Numbers in Table 1 denote storage piles to be visited.

Table 1. Vehicles schedule

	Tours visiting storage piles									
Vehicle	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Vehicle 1	5	4	3	5	5	1	3	2	1	5
Vehicle 2	5	3	1	2	5	5	2	3	1	3
Vehicle 3	1	2	1	5	1	5	3	5	1	2
Vehicle 4	2	5	3	4	2	2	2	1	5	2
Vehicle 5	4	2	4	1	4	4	5	1	2	2
Vehicle 6	4	3	3	5	1	3	4	2	1	2
Vehicle 7	5	5	3	1	2	4	3	2	4	5
Vehicle 8	2	4	2	3	5	3	4	4	5	3
...	...	...	...	...	...	...	...	...	...	...

Inputs related to sugar beet loading and unloading times as well as sampling and weighing times and its probability distributions are based on results of Žitňák and Korenko (2011).

Accordingly to their findings, average time for beet sampling was 1.92 min and average weighing time is 1.93 min, where both processes are assumed to be normally distributed with given means and variation coefficient 0.1. Loading beet on storage piles follows Lognormal probability distribution with mean of 11.67min and st.dev 4.53min of corresponding Normal distribution. Typical unloading time of vehicles in mill, using dry concept, accordingly to Asadi (2007), is assumed to be normally distributed with mean of 8min and variation coefficient 0.2. Those mill processes service times are about 14min in total and they are used in the first scenario (*14' service time*), while in the second we doubled service times (*28' service times*) from the first scenario. The loss in sucrose content per time unit is based on Asadi (2007), while in this research we analysed the expected daily loss (β) of 0.5% 1% and 2%. Vehicle speed in [km/h] is assumed to be uniformly distributed in range 40-50km/h and 30-40km/h for empty and loaded vehicles respectively.

Terminating condition for all simulations experiments was realization of all scheduled beet collection tours. Number of replications in each particular simulation experiment was 5.

As a measure of prioritization strategies application effects, we analyze total sugar loss in supply chain, which is measured relatively to sugar content at the beginning of supply process, by using equation (2).

$$TotLossF,P = 100 \cdot \frac{AvailableSug - DeliveredF,P}{AvailableSug} \; [\%] \tag{2}$$

Effects of applying priority service strategy in mills' queues on savings of sugar content in a beet are estimated as absolute (*Saving effects - t*), as well as relative values (*Saving effects - %*). Absolute savings (*AbsSav*) in tons of sugar are calculated as difference between the quantities of delivered sugar under **PRIORITY** service strategy (*DeliveredP*) and **FIFO** service strategy (*DeliveredF*). Relative savings (*RelSav*) in % are calculated by using equation (3).

$$RelSav = 100 \cdot \frac{DeliveredP - DeliveredF}{AvailableSug} \; [\%] \tag{3}$$

where:

TotLossF,P	Total loss of sugar content during the supply process realization, under FIFO (F), and Priority (P), service strategies
AvailableSug	Sugar content in beet stored on piles at the beginning of supply process
DeliveredF,P	Content of sugar in mill after unloading, under FIFO (F), and Priority (P), service strategies
RelSav	Relative savings in percentage of delivered sugar as a result of application of the Priority service strategy
AbsSav	Absolute savings in tons of sugar delivered, as a result of application of the Priority service strategy

The results for two groups of simulation experiments which corresponds to 6250 (*lower supply intensity*) and 12500 (*higher supply intensity*) tons of beet supply are shown in Tables 2 and 3, respectively. In each mentioned group of experiments, we analyzed six scenarios that correspond to different values of the loss in sucrose content per time unit β and different service rates in mill processes. For the case of lower supply intensity (6250 t daily) was analyzed only single unloading channel in the mill, while in the case of higher supply intensity (12500 t daily), two variants were analysed: single unloading channel in the mill, and two unloading channels of the same capacity in the mill.

Table 2. Results of simulation experiments (*lower supply intensity of 6250 t*)

Single unloading channel in the mill	Available sugar on piles (t)	**FIFO** service		**PRIORITY** service		RelSav effects (%)	AbsSav effects (t)
		DeliveredF (t)	TotLossF (%)	DeliveredP (t)	TotLossP (%)		
β=0.5%, 14' service time	1287.3050	1282.5438	0.3699	1282.5563	0.3689	0.0010	0.0125
β=0.5%, 28' service time	1287.3050	1274.8625	0.9666	1274.9688	0.9583	0.0083	0.1063
β=1%, 14' service time	1287.3050	1274.7375	0.9763	1274.7563	0.9748	0.0015	0.0187
β=1%, 28' service time	1287.3050	1259.5250	2.1580	1259.6375	2.1493	0.0015	0.1125
β=2%, 14' service time	1287.3050	1259.2000	2.1832	1259.3813	2.1692	0.0087	0.1812
β=2%, 28' service time	1287.3050	1229.3500	4.5020	1230.1313	4.4414	0.0141	0.7813

Table 3. Results of simulation experiments (*higher supply intensity of 12500 t*)

Single unloading channel in the mill	Available sugar on piles (t)	**FIFO** service		**PRIORITY** service		RelSav effects (%)	AbsSav effects (t)
		DeliveredF (t)	TotLossF (%)	DeliveredP (t)	TotLossP (%)		
β=0.5%, 14' service in mill	2582.0225	2552.8500	1.1298	2553.4500	1.1066	0.0232	0.6000
β=0.5%, 28' service in mill	2582.0225	2522.5375	2.3038	2523.1625	2.2796	0.0242	0.6250
β=1%, 14' service in mill	2582.0225	2522.0000	2.3246	2523.0625	2.2835	0.0411	1.0625
β=1%, 28' service in mill	2582.0225	2462.6750	4.6222	2464.3750	4.5564	0.0411	1.7000
β=2%, 14' service in mill	2582.0225	2461.3250	4.6745	2462.8125	4.6169	0.0658	1.4875
β=2%, 28' service in mill	2582.0225	2347.7250	9.0742	2350.9875	8.9478	0.0576	3.2625
Two unloading channels in the mill	Available sugar on piles (t)	**FIFO** service		**PRIORITY** service		RelSav effects (%)	AbsSav effects (t)
		DeliveredF (t)	TotLossF (%)	DeliveredP (t)	TotLossP (%)		
β=0.5%, 14' service in mill	2582.0225	2552.8750	1.1289	2552.9375	1.1264	0.0024	0.0625
β=0.5%, 28' service in mill	2582.0225	2568.1750	0.5363	2568.3125	0.5310	0.0053	0.1375
β=1%, 14' service in mill	2582.0225	2522.0375	2.3232	2522.2375	2.3154	0.0077	0.2000
β=1%, 28' service in mill	2582.0225	2552.3500	1.1492	2552.6250	1.1385	0.0106	0.2750
β=2%, 14' service in mill	2582.0225	2520.8500	2.3692	2521.4000	2.3479	0.0213	0.5500
β=2%, 28' service in mill	2582.0225	2461.4000	4.6716	2462.7625	4.6188	0.0528	1.3625

The results obtained by simulation obviously show that the application of service priority strategy in deteriorating goods supply could introduce positive effects as a results, as it was the authors main hypothesis in this research. Service priority strategy outperforms FIFO strategy (Figure 4), and since its application is based only on organizational activities, it can be considered as very promising rationalization potential.

Maybe the main problem of the practical application of this concept is in estimating quality of deteriorating goods at the beginning of supply process, and in finding appropriate function that can be used to estimate quality deterioration in time. In the case of sugar beet, as appropriate, we propose eq.(1), although the beet quality also depends on other factors, like humidity, temperature, etc. On the other side, recent advances in technology offer mobile instruments which can measure certain quality of goods attributes, so that, in case of sugar beet, some authors analyse usage of portable visible and near-infrared spectroscopy (Pan et al., 2015). Hence, instead of modelling deterioration, in this way it can be measured, and priority could be defined on that base. Nevertheless, priority queues, i.e. service based on the priority is promising concept which can decrease deterioration of goods, as it has been shown in this research, which could be considered as a beginning of more wider research in this area.

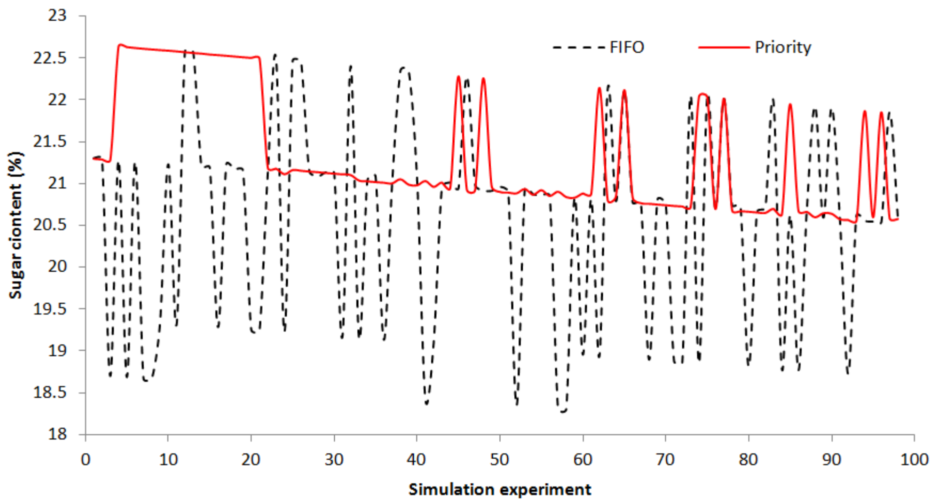

Figure 4. Example of simulated sugar content in realized 100 vehicle tours under FIFO and Priority service strategies

5. CONCLUDING REMARKS

This research represents an attempt to develop a framework for simulation analysis of potentials which are related with introducing the priority service strategies in deteriorating goods supply. This idea may have wide application in different supply systems oriented to deteriorating products, mostly agricultural, in which goods lose its quality during a time. The paper delivers two main contribution. One is related to the concept of the simulation model used to estimate potential effects of priority service, while the other is related with the practical implementation, since the simulation analysis of the concept shows positive effects which need only changes in organization.

The concept proposed in this research, helps dispatcher in defining vehicles schedule making the supply process more efficient and economical. In this way, processes which are essentially uncertain and very complex, can be improved in an relatively modest way.

Further research should analyse other possibilities in optimization of deteriorating goods supply. One is to analyse possibilities and effect of using portable instruments for quality determination. Also, an important research direction is in combining of simulation and optimization with the objective of optimal scheduling of supply vehicles in real stochastic supply systems, considering the service priority as one of improvement potentials.

ACKNOWLEDGMENT

This work was supported by the Ministry of Education, Science and Technical development of the Government of the Republic of Serbia through the projects TR36006 and 36010 for the period 2011-2019.

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APPLICATION OF THE METHODOLOGY FOR CALCULATING CARGO HANDLING TARRIFS AT RIVER PORTS

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Abstract: *In this paper, we will discuss several methodologies for calculating cargo handling tariffs at river ports. We will present port tariffs calculations based on the Principle of total costs and present the methodology. We will apply described methodology on one case study: Port "Danube" Pancevo.*

Keywords*: River ports, Cargo handling, Port tariffs*

1. INTRODUCTION

Port pricing issues are often analyzed in the context of port revenue and cost recovery. However, the process of privatization, introduction of competition and liberalization is forcing these tariffs be determined according to market mechanisms. Growing number of ports are implementing market pricing when determining tariffs. Market pricing is the method of associating port tariffs to potential market demand and sensitivity in order to maximize cash flow, attain good utilization of facilities, counter competition, stimulate market growth and improve profitability. When implementing market pricing, it is important to guarantee that the full rate traffic is not diverted to the lower rate in an attempt to generate a higher volume of business. Existing tariff levels, costs, competition, agreements with shipping companies and market sensitivity should be carefully evaluated (Trujillo and Nombela, 1999).

Port operators are required to establish a detailed and precise tariff structure. Frequent changes can be a source of confusion for port users. Therefore, the structure of port tariffs should be designed to last for a long period of time (ESCAP and KMI, 2002).

Ports tend to follow the following goals when determining tariffs (ESCAP and KMI, 2002):

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- Promote the most efficient use of facilities - the main goal of port charging is to ensure that port facilities are used in the most efficient way.
- Retain the benefits that results from investments within the country - the goal of setting port tariffs is of particular interest to ports in developing countries.
- Return sufficient revenue to meet financial goals - this goal relates to the construction of financial reserves to prepare for unexpected revenue losses or an increase in costs.

Also, the important objectives that the tariff system needs to fulfill are (ESCAP and KMI, 2002):

- Establishment of a clear structure for the fair and flexible business relationship between port operators and users.
- Prevention of double payments.
- Development of congestion prevention mechanisms: Port congestion can occur when traffic is increasing, and the port's capacity remains unchanged. In this situation, congestion can be prevented by introducing tariffs to prevent congestion.
- Simplification of the tariff system of the port, from which it is easy to find out who pays and how much.

The main objective of this work is to determine port tariffs based on the Principle of total costs, which is discussed in the following section. We will present it on one example: Port "Danube" Pancevo.

2. DESCRIPTION OF THE EXISTING METHODOLOGIES FOR CALCULATION OF PORT TARIFFS

For all port tariffs charged for specific services or for the use of a clearly identified port's infrastructure, it is proposed that the term: *specific port tariff (tarif portuaire specifique, tarifa portuaria especifica)* should be used. This general term will apply to such varied tariffs as: berth occupancy; berthing/unberthing; pilotage; towage; mooring, stevedoring; cargo-handling on quay; receiving/delivery, storage; warehousing; rent of equipment, etc. These tariffs are usually based on the costs incurred in providing the services and are dependent on types of costs taken into consideration (United Nations Report, 1975).

There are three basic groups of tariffs: tariffs associated with the provision of services; tariffs associated to the provision of facilities; and general tariffs (Value-based, corresponding to the value of the vessel, and cargo). These three groups of tariffs can be determined by different cost-based pricing approaches, average cost pricing, variable cost pricing, marginal cost pricing, and total cost pricing:

(a) Average cost pricing: This pricing approach is based on the average cost determined by adding the total fixed and variable costs and dividing this sum by the projected demand for the service. Port tariffs so derived have the advantage of assuring that the revenues collected will equal the total costs, assuming that the projected demand is realized. This approach gives priority to achieving an overall financial target, namely a nonsubsidized price. For ports with a high proportion of fixed costs, increasing the throughput may significantly decrease the average or per unit cost. A disadvantage of average cost pricing is that there is a tendency to set prices higher when demand is weak, and lower when demand is high. Furthermore, this approach excludes those clients that cannot afford to pay a given price, but might be able to pay a lower one, perhaps one based only on the variable cost (United Nations Report, 1975).

(b) Variable cost pricing: Pricing based on the unit variable cost is determined by dividing the total variable costs by the projected demand for the services and the facilities. In general, this approach is only appropriate where variable costs are a large share of the total costs as in labor-intensive break-bulk cargo handling operations due to the use of temporary labor. Tariffs based only on variable costs have generally not been introduced, even though they encourage efficient use of port resources. The reason is that many port services and facilities have variable costs that are too small to serve as the basis for a tariff and to cover the port's expenditures. If a tariff is based on variable costs, the losses incurred need to be offset by other tariffs. However, the pricing based on variable costs can achieve the operational objective of maximizing the use of services and the financial objective of covering the variable costs of these services (United Nations Report, 1975).

(c) Marginal cost pricing: Pricing based on the unit marginal cost is determined by dividing the marginal costs by the projected marginal demand for the services. The tariff based on the unit marginal cost requires that the relationship between variable costs and expected throughput demand be known for the period during which the price will prevail. Therefore, it is necessary to estimate the change in resource productivity as demand increases. This information is difficult and time consuming to obtain. Change in variable costs over a long period of time must be correlated with variations in demand. These inherent problems have led to unit marginal costs not being used to set port tariffs, except where explicit surcharges have been introduced to cover overtime, a third shift, or holiday premiums for labor. It may be useful to set the level of port charges of seasonal traffic on the basis of unit marginal costs because it is inefficient to provide additional capacity for these relatively short periods. Furthermore, there is a tariff ceiling, which is determined by the degree of congestion of the facilities, as users face much higher operating costs than the actual charge applied by the port authority. Marginal cost pricing, however, has some problems. First, it is very difficult to estimate and distribute the marginal costs, particularly the estimation of the short-term and the long-term marginal costs, and the distribution of the marginal costs among the charge items. Second, marginal cost pricing should be based on competitive market principles. But the port industry is characterized by monopoly. Third, if a port authority suffers from a shortage of demand and makes operation losses amounting to the balance between the marginal costs and average costs, then compensation from other sources should be made. For these reasons, marginal cost pricing has some limitations as a basic port pricing theory, even though it is economically efficient, flexible and the fairest pricing tool (United Nations Report, 1975).

(d) Total cost pricing: The Principle of total costs is the method of determining tariffs where both fixed and variable costs are included. It is applied when all services are the same. This principle is often used in the economy sector that is regulated or partially regulated (Bugarinović, 2014). Most costs related to infrastructure are fixed and include the capital costs and the maintenance costs caused by wear and tear during operation. Utilities are also treated as fixed costs, unless they are explicitly related to the activity on the berth, i.e. power for crane operations, or provided to vessels (electricity and water). Capital costs of equipment, salaries and benefits of permanent staff, and administrative expenses are also considered in this category. Variable costs include: expenditures on fuel, lubricants, and other consumables used in the operation of equipment; expenditures on scheduled maintenance and repairs related to equipment use; payments for equipment rented on a daily or weekly basis; the wages of casual labor hired on a daily or shift basis; and overtime of permanent staff (United Nations Report, 1995).

In this paper, we used the economic principle for tariffs calculation based on total costs.

3. METHODOLOGY APPLICATION. CASE STUDY: PORT "DANUBE" PANCEVO

One of the most important services provided to cargo vessels at ports is what is generically labeled as *cargo handling*. This includes all services related to the movement of cargo from/to vessels and across port facilities. Cargo handling services are very important for port users in terms of total tariffs. Since these tariffs significantly affect a port's competitive position, it is crucial that they are closely related to the real costs of services provided F In other words, the inland port operating companies or port operators are interested in precise calculation of costs of provided port services.

This paper considers Port "Danube" Pancevo which provides a large number of services to port users for different types and sizes of cargo. Different types of infrastructure and suprastructure are used for different services, and considering that different services require a different number of employees, for each individual port service it is necessary to determine a correct tariff.

At the Port "Danube" Pancevo, we looked at the fertilizer unloading service and considered the service of unloading fertilizer in bulk from the vessel by a quay crane. The fertilizer handling technology at the Port "Danube" Pancevo is described in detail in the work of Pjevčević et al. (2013, 2018). Self-propelled cargo vessels bring fertilizer to the port. Vessels carrying capacities are assumed to be 1000 tons. Unloading operations are done at loading/unloading areas using quay cranes. The loading/unloading area is adjacent to the berth which is under the cranes. Once a full vessel is berthed to unload fertilizer, it will remain in its location until an unloading process is completed. Bulk fertilizer is unloaded from a vessel by a quay crane, and loaded into a fertilizer-packing machine, which is placed at the loading/unloading area adjacent to the berth. A fertilizer-packing machine is used to pack fertilizer into plastic bags which weigh 50 kg each. Afterwards, bags are transported by a belt conveyer to the temporary storage area where they are palletized and prepared for further distribution.

In order to determine the port tariff, it is necessary to calculate total costs that the Port has when carrying out cargo unloading service from a vessel to the loading/unloading area adjacent to the berth. Total port costs, T (EUR / h), consist of: Berth costs, T_b (EUR / h), Quay crane costs, T_r (EUR / h), Labor costs, T_l (EUR / h), Shipping companies costs, T_s (EUR / h) and Cargo costs, T_u (EUR / h).

The objectives of the pricing system must be related to the strategy of the port. The first task is the estimation of future levels of traffic as it will determine the total revenue generated (United Nations Report, 1995). Therefore, the annual throughput of fertilizer that the Port could expect was forecasted by the Least Squares Method and it was 69889 t (Prskalo, 2018). Assuming that fertilizer is delivered to the Port by vessels of the carrying capacity of 1000 t, we can calculate the number of vessels to be unloaded. It is necessary to unload 70 vessels at the Port.

3.1 Berth costs

We assumed that the inland port operator is the owner of port's infrastructure. Under this assumption, costs of one berth can be calculated as the costs of depreciation and maintenance of the area used for unloading fertilizer. For the calculation of the costs of construction of one berth, we have assumed that the price per working meter of the berth is 25000 EUR / m and the lifetime is N = 50 years. Thus, the costs of constructing one berth in the length of 120m amount to 3 M EUR. We assumed that annual maintenance cost for the berth is 2 % of the construction cost, which is 60000 EUR (Thoresen, 2010).

Costs of depreciation and maintenance of one berth are

$$B=\left[B_i\cdot\frac{i\cdot(1+i)^N}{(1+i)^N-1}+M_b\right]\cdot\frac{1}{365\cdot 24}\quad\left[EUR/h\right]\tag{1}$$

$$B=\left[3000000\cdot\frac{0.12\cdot(1+0.12)^{50}}{(1+0.12)^{50}-1}+60000\right]\cdot\frac{1}{365\cdot 24}=41.24\quad\left[EUR/h\right]\tag{2}$$

Therefore, Berth costs are equal to 41.24 [EUR / h].

3.2 Quay crane costs

At the Port "Danube" Pancevo, the fertilizer unloading is carried out at one berth with one quay crane. The production rate of the crane in the realization of the considered unloading task is calculated in the work of Prskalo (2018), and it equals 201.33 t / h.

For the calculation of depreciation, we assumed that the price of the crane was 1000000 EUR, and that the lifetime of the crane is 20 years. We assumed that the annual maintenance cost of the crane is 2% of the price of the crane (Thoresen, 2010). Under these assumptions, the costs of depreciation and maintenance of a crane are 17.56 [EUR / h].

3.3 Labor costs

For our calculation, we assumed that the navigation period is 300 days due to unfavorable weather conditions during January and February. We assumed that the fertilizer is unloaded during one 8 hour long shift. When we multiply the navigation period with working hours and the number of shifts, we get the annual working hours of the Port in hours (2400 h).

The vessels' arrival rate, λ, is calculated as 70 / 2400 and is 0.0291 [vessels / h]. The vessel's service time, *t*, is obtained by dividing the self-propelled cargo vessel carrying capacity with the production rate of the crane. It is 4.966 h. The minimum working time of the team of workers by one vessel is 4 h. The paid working time of the team is the maximum of the minimum working time of the team and the vessel's service time, which is 4.966 h.

We calculated the labor costs as the product of the arrival rate of vessels, the paid working time of the team, and the cost of one team of workers, which is assumed to be 35 [EUR / team-hour] (Milešić, 2018). Therefore, labor costs are 0.0291*1*4.966*35, which is equal to 5.05 [EUR / h].

3.4 Shipping companies' costs

The model of the classic single-channel Erlang queuing system is used in order to determine the vessel's average waiting time at the Port. The input parameters are the service rate and the vessels' arrival rate. The M/M/1/∞ queuing system, the simplest queuing system, has a Poisson arrival distribution, an exponential service time distribution and a single channel (one server). It is assumed that there is just a single queue (waiting line) and vessels move from this single queue to the berth (server). The length of the queue is indefinite.

The service rate is the number of vessels that the Port can serve per hour:

$$\mu = \frac{1}{t+m} = \frac{1}{4.966+1} = 0.168 \qquad [vessels/h] \tag{3}$$

where *m* is a maneuvering time [h].

We assumed that the maneuvering time was 1h (Prskalo, 2018).

Average vessel's delay or waiting time is calculated as:

$$w = \frac{1}{\mu-\lambda} - \frac{1}{\mu} = \frac{1}{0.168-0.0291} - \frac{1}{0.168} = 1.247 \qquad [h] \tag{4}$$

The total time that a vessel spends at the Port is particularly important because it is the part of the costs of using the vessel, and therefore can affect the ability of the shipping company, to maximally use resources. We assumed that the total agreed-upon time that the vessel spends at the Port is 5 hours (Prskalo, 2018). The cost of any additional hour is 41.67 [EUR / h] (Prskalo, 2018).

In this example, the vessel stayed at the Port 2.199 hours longer than the agreed-upon time:

$$s = w + \frac{1}{\mu} - 5 = 1.247 + \frac{1}{0.168} - 5 = 2.199 \qquad [h] \tag{5}$$

We can calculate shipping companies' costs as follows:

$$T_s = \lambda \cdot s \cdot S \qquad [EUR/h] \tag{6}$$

where:

s - time that a vessel spends at the Port over agreed-upon time [h]
S - unit cost of the vessel at the Port [EUR/h]

$$T_s = 0.0291 \cdot 2.199 \cdot 41.67 = 2.66 \qquad [EUR/h] \tag{7}$$

3.5 Cargo Costs

In our calculation, we assumed that the cargo waiting costs at the Port are 20 [EUR/h]. We calculated cargo costs by multiplying the vessels' arrival rate with the average time that the vessel spends at the Port longer than agreed-upon time, and the unit cargo waiting costs at the Port.

$$T_u = 0.0291 \cdot 2.199 \cdot 20 = 1.28 \qquad [EUR/h] \tag{8}$$

3.6 Total costs

As stated above, the total costs of the Port when unloading the forecasted amount of bulk fertilizer from vessels to the loading/unloading area are:

$$T = 41.24 + 17.56 + 5.05 + 2.666 + 1.28 = 67.8 \quad [EUR/h] \quad (9)$$

3.7 Cargo handling tariff

In order to establish the appropriate tariff for the fertilizer unloading service, it was first necessary to calculate the costs incurred when unloading the fertilizer. The unit total costs of the Port per ton of fertilizer is obtained as annual total costs divided by the annual amount of fertilizer which equals 0.489 [EUR / t].

3.8 Sensitivity analysis

Many variables, including the future performance and prices of the port facilities and services will affect the future tariffs and traffic, and some of them cannot be controlled by the port operator (United Nations Report, 1995).

For example, if the costs of one team of workers increase from 35 [EUR /team-hour] to 45 [EUR / team-hour], labor costs will be 6.5 [EUR /h], and the total costs will be 69.25 [EUR /h]. According to the applied methodology, a tariff based on the unit total costs of 0.499 [EUR / t] would cover expenses incurred in fertilizer handling on quay provided that the annual throughput of fertilizer was at least 69889 t.

For example, if the cargo waiting costs at the Port increase from 20 [EUR/h] to 30 [EUR/h], total costs will be 68.44 [EUR /h]. According to the applied methodology, a tariff based on the unit total costs of 0.493 [EUR / t] would cover expenses incurred in fertilizer handling on quay provided that the annual throughput of fertilizer was at least 69889 t.

4. CONCLUSION

Of the total costs involved in moving goods through a port, cargo handling costs are the most important (between 70% and 90% of the total costs, approximately, depending on the type of cargo) (Trujillo and Nombela, 1999). As cargo handling costs are important to port users, these costs are of utmost importance to port operators as well. Therefore, this is one of the services that must be supervised more closely by regulators in order to ensure cost-efficient port operations. The tariffs have to be correctly calculated so that all incurred costs are covered.

According to the applied methodology, a tariff based on the unit total costs of 0.489 [EUR / t] would cover expenses incurred in fertilizer handling on quay provided that the annual throughput of fertilizer was at least 69889 t.

ACKNOWLEDGMENT

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia [grant number TR36002].

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Part II

LOGISTICS CONCEPTS AND STRATEGIES

COMPETENCE REQUIREMENTS FOR LOGISTICS MANAGERS IN SERBIA: A LONGITUDINAL ASSESSMENT

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Abstract: *Today, logistics and supply chain management is attractive and very demanding field for a professional career. The competences that the employers in this field require from employees continue to evolve and change. This paper aims to provide a longitudinal assessment of two studies of online ads of logistics and supply chain management jobs conducted in the Republic of Serbia. Both these studies used the same methodology of collected, coded and analysed job ads. The ads were analysed by deductive content analysis and related quantitative indicators. The aim is to reinforce the results of these studies by searching statistical similarities in professional and fundamental competences of logistics and supply chain managers. Also, several studies done in the US, the UK, Germany, Brazil, etc. will be used for drawing conclusions. The outcomes of this paper can be valuable to educators, to educational and professional institutions, and to other interested parties.*

Keywords: *logistics and supply chain professionals, competence, longitudinal study, the Republic of Serbia.*

1. INTRODUCTION

Logistics and supply chain management (SCM) is one of the most important fields for the competitiveness of participants in supply chains and total supply chains. In this field competences of the logistics and SCM professionals are more important than physical infrastructure and information and communication processes. The logistics and SCM professionals should have a right combination of competences to continually manage processes in supply chain, and to improve them with collaboration and integration, in order to satisfy real customer requirements. The required competences of these professionals can vary from one country to another, from one industry to another, from one market to another, from one supply chain to another, from one company to another,

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and from one process to another. It is very important that logistics and SCM professionals are well educated, trained and 'equipped' with both professional and fundamental competences. The focus here will be on what logistics and supply chain managers need to do in companies in the Republic of Serbia, and what important competences they need to have to do what they need to do in that companies.

The reminder of the paper is organized as follows. In the next section, a review of studies on competence frameworks and models for logistics and SCM professionals is given. Then, the methodology of this longitudinal study is presented. The following section presented the results of this longitudinal assessment of two studies of logistics and SCM job ads conducted in the Republic of Serbia and gave discussion of these results. Finally, some conclusions are offered.

2. LITERATURE REVIEW

The connection between SCM and human resource management (HRM) can be viewed as a key to business success of supply chains (e.g. Derwik et al., 2016; Derwik and Hellström, 2017; Sun and Song, 2018). There are a number of studies that have considered the HRM issues in the logistics and SCM field. Some of these studies are focused on developing new competence framework or model for logistics and SCM professionals, and some of them tried to test the importance of different competences of these professionals (e.g. Cvetić et al., 2017; Cvetić et al., 2018).

Here, it is valuable to start with the well-known BLM (Business, Logistics and Management) framework developed by Poist in 1984 (Murphy and Poist, 1991). The BLM framework has been customized several times by the same or other interested researchers (e.g. Murphy and Poist, 1991; Murphy and Poist, 2006; Murphy and Poist, 2007; Thai, 2012; de Almeida Vilela et al., 2018), often, in order to reveal the importance of business, logistics and management competence requirements for logistics and SCM professionals. Almost all of these studies confirmed that these professionals first should be managers, than logisticians and businessmens. The empirical studies which used the BLM framework were carried out in the US, Ireland, Spain, Singapore, Malaysia and Australia, according to Cvetić et al., 2018. Several researchers try to reveal the most important competences of logistics and SCM professionals. Thus, Gammelgaard and Larson (2001) identified 45 SCM competences and grouped them into the three groups: interpersonal/managerial basic skills, quantitative/technological skills and SCM core skills. Giunipero with colleagues have been tried to find the most important skills for supply managers (Giunipero and Pearcy, 2000; Giunipero et al., 2005; Giunipero at al., 2006). The very well-known association for supply chain management APICS developed five competence models for logistics and SCM professionals in 2011. These competence models were slightly, more visually, were changed in 2014 (APICS, 2014). Cvetić developed the competence model for logistics and supply chain managers in 2014 (Cvetić, 2016), and further used it with her colleagues for empirical findings in the Republic of Serbia (e.g. Cvetić et al., 2015; Cvetić et al., 2017; Cvetić et al., 2018). Derwik and Hellström (2017) determined the competence in SCM as a combination of four elements: functional competence, relational competence, managerial competence and behavioral competence; on the individual, intra-organizational and inter-organizational levels. Sun and Song (2018) identified the following five competence categories: professional knowledge, business management, communication and teamwork, self-management and improvement, and social responsibility. Campos et al. (2019) examined competences for SCM professionals in the mid-sized supermarket sector in Brazil. Bak et al. (2019) put attention to the required soft skills for supply chain managers.

Some researchers try to identify really important competences from logistics and SCM professionals throughout the empirical studies based on job ads analysis. Radovilsky, Hegde and Kandasamy probably were the first authors who conducted logistics job ads analysis in 2007 (see e.g. Radovilsky & Hegde, 2012, Cvetić et al., 2017). Sodhi et al. (2008) analysed job ads for MBA graduates from the field of SCM and offer interesting view about important supply chain topics for leading business schools in the US. Rossetti and Dooley (2010) examined SCM job ads and suggested the three major types of SCM jobs, namely sourcing manager, operations consultant and supply chain information manager. Cacciolatti with colleagues analysed SCM job ads in the UK labour market and provided some good propositions for educational institutions (Cacciolatti and Molinero, 2013; Cacciolatti et al., 2017). Kotzab and Wünsche (2015) examined logistics jobs in Germany and made relation with primary and secondary qualifications. Cvetić, Vasiljević and Danilović collected logistics and SCM job ads in the Republic of Serbia in 2014 and 2017 and indicated on the most required professional and fundamental competences of logistics and supply chain managers (e.g. Cvetić et al., 2017; Cvetić et al., 2018). Kotzab et al. (2018) examined key competences of logistics and SCM professionals from the perspective of lifelong learning.

Of course, there are other studies that have examined the general or specific connections of both HRM and SCM domains.

3. METHODOLOGY

The focus of this study is to provide a longitudinal assessment of two studies of online logistics and SCM job ads conducted in the Republic of Serbia in 2014 and 2017. Both these studies used the same methodology of collected, coded and analysed job ads.

Probably the first study of logistics and SCM job ads in the Republic of Serbia was conducted in 2014 (Cvetic et al., 2015; Cvetic, 2016; Cvetić et al., 2017). Then, job ads were collected from the 1st April to the 1st July 2014 on the well-known domestic on-line job portal Infostud (http://poslovi.infostud.com) and the total of 35 relevant ads was collected and analysed. The second study of logistics and SCM job ads in the Republic of Serbia was conducted in 2017 (Cvetić et al., 2018). The relevant job ads were collected from the 1st March to the 31st May 2017 on the same job portal Infostud and the total of 65 ads was collected and further analysed.

The content of every job ads was carefully manually coded by using deductive content analysis (e.g. Cvetić, 2016; DeFranco and Laplante, 2017; Cvetić et al., 2017). The ground for analysis was the previously developed competence model for logistics and supply chain managers (described in Cvetić, 2016) and the supporting MS Excel data base. This competence model for logistics and supply chain managers distinguishes the three levels of competences: the level of education and relevant work experience, and the levels of professional and fundamental competences. Additionally, the MS Excel data base is made according to this competence model and was used as a supporting tool for deductive content analysis. This was a way how the qualitative data were transformed into the quantitative data given through the two quantitative indicators. These quantitative indicators are:

P_k - the percentage of ads in which the specified competence has at least one occurrence [%];

M_k - the average number of occurrences of the specified competence per job ad [1].

The percentage of ads in which the specified competence has at least one occurrence (P_k) represents the relation between the number of ads in which the competence k ($k = 1,\ldots,m$) has at least one occurrence (A_k) and the total number of ads (N).

$$P_k = \frac{A_k}{N} \cdot 100 \quad [\%] \tag{1}$$

The average number of occurrences of the specified competence per job ad (M_k) represents the relation between the total number of occurrences of competence k in all ads (C_k) and the total number of ads (N).

$$M_k = \frac{C_k}{N} \quad [1] \tag{2}$$

At the end, the data was used for providing a longitudinal assessment of these two studies of online logistics and SCM job ads conducted in the Republic of Serbia. The aim is to reinforce the results of these studies by searching statistical similarities in professional and fundamental competences of logistics and supply chain managers.

4. RESULTS

The number of logistics and SCM job ads collected in the Republic of Serbia in 2014 was 35, and in 2017 was 65. This can be viewed as some kind of increase in logistics and SCM job offers between the two observed time intervals (Table 1). The international companies that do business in the Republic of Serbia offered higher number of jobs than the domestic companies. These jobs were offered in different sections, mostly in wholesale and retail trade, repair of motor vehicles and motorcycles, manufacturing section and transportation and storage section. The largest number of jobs was offered in Belgrade and Novi Sad. The logistics and SCM job ads were published even equally in English and Serbian language.

The logistics and SCM job ads vary in structure, but generally, they include the data about the job title, job location, job description, required competences and application instructions (Cvetić et al., 2017). The data about salary were not included (Cvetić et al., 2017, Cvetić et al., 2018).

The results about the level of education show that candidates need to have at least a university bachelor's degree. This was requirement in 60% of the observed job offers, interesting, in both these two time intervals (see Cvetić et al., 2017, Cvetić et al., 2018). Usually, the university bachelor's degree from a specific faculty is not required and employers gave attention to the preferred fields of study (e.g. logistics, engineering, technical field, traffic engineering, operations management, economics, business administration, international trade). The possibility of having other school qualification was also sometimes mentioned, but of course, in combination with additional extensive managerial experience (Cvetić et al., 2017, Cvetić et al., 2018). Requirements regarding previous work experience were very strictly at the first sight to the job offers. Almost, for more than 80% of logistics and SCM jobs, the relevant work experience was obligatory (Cvetić et al., 2017, Cvetić et al., 2018). A lot of job offers were for candidates with at least one/two/three/four years of professional experience. Also, there were job offers for candidates with over eight years of relevant work experience (Cvetić et al., 2018).

Table 1. Logistics and SCM Job Offers Profile

Empirical study	**2014.**	**2017.**
Number of logistics and SCM jobs offers	35	65
Job offers by companies		
Domestic companies	31.43 [%]	40.00 [%]
International companies	68.57 [%]	60.00 [%]
Job offers by industry		
Wholesale and retail trade; repair of motor vehicles and motorcycles	17.14 [%]	36.92 [%]
Manufacturing	57.14 [%]	35.38 [%]
Transportation and storage	17.14 [%]	12.31 [%]
Information and communication	0	6.15 [%]
Administrative and support service activities	0	6.15 [%]
Professional, scientific and technical activities	0	3.08 [%]
Construction	5.71 [%]	0
Agriculture, forestry and fishing	2.86 [%]	0
Job offers by town		
Belgrade	51.43 [%]	60.00 [%]
Novi Sad	11.43 [%]	13.85 [%]
Subotica	2.86 [%]	6.15 [%]
Indjija	2.86 [%]	3.08 [%]
Sabac	0	3.08 [%]
Vrbas	0	3.08 [%]
Kikinda	0	1.54 [%]
Kladovo	0	1.54 [%]
Leskovac	0	1.54 [%]
Ruma	11.43 [%]	1.54 [%]
Senta	0	1.54 [%]
Smederevo	0	1.54 [%]
Zajecar	0	1.54 [%]
Kragujevac	5.71 [%]	0
Aleksinac	2.86 [%]	0
Backa Palanka	2.86 [%]	0
Gornji Milanovac	2.86 [%]	0
Nis	2.86 [%]	0
Zrenjanin	2.86 [%]	0
Job offers by language		
Serbian	54.29 [%]	47.69 [%]
English	45.71 [%]	52.31 [%]

When it comes to the professional and fundamental competences of logistics and supply chain managers, two quantitative indicators were calculated and used, as previously mentioned. These are the percentage of ads in which the specified competence has at least one occurrence (P_k); and the average number of occurrences of the specified competence per job ad (M_k) (Tables 2 and 3). It can be concluded that the seven most required professional competences of logistics and supply chain manager in the Republic of Serbia are: performance management, customer relationship management, demand forecasting and inventory management, warehouse management, supplier relationship management, transportation management, and distribution management (Table 2). On the other side, the two least required professional competences are: product introduction into the market, and designing supply chain. The statistically significant difference was found between the percentages of ads in which the specified professional competence has at least one occurrence in 2014 and 2017 (Wilcoxon signed-rank test: N=15; Z=-1.988; p=0.047). Positive ranks (12) outnumbered negative ranks (3), which mean that between the two observed time intervals from 2014 and 2017 the indicator P_k has grown. The statistically significant difference was not found between the average numbers of occurrences of the specified professional competence per job ad in 2014 and 2017 (Wilcoxon signed-rank test: N=15; Z=-1.712; p=0.087).

Table 2. Indicators of professional competences of logistics and supply chain manager

Professional competences	P_k **[%]**		M_k **[1]**	
Empirical study	**2014.**	**2017.**	**2014.**	**2017.**
Performance management	74.29	80.00	2.23	3.17
Customer relationship management	68.57	73.85	1.54	1.78
Demand forecasting and inventory management	71.43	69.23	2.20	2.14
Warehouse management	40.00	61.54	1.09	1.74
Supplier relationship management	48.57	60.00	1.51	1.95
Transportation management	37.14	56.92	0.77	1.89
Distribution management	34.29	50.77	0.94	1.26
International logistics	22.86	46.15	0.31	0.89
IST as a function of logistics support	34.29	38.46	0.71	0.66
Manufacturing management	45.71	33.85	1.49	1.29
Lean management	31.43	21.54	1.23	0.51
Maintenance management	17.14	18.46	0.29	0.58
Reverse and green logistics	11.43	12.31	0.17	0.17
Product introduction into the market	5.71	6.15	0.14	0.06
Designing supply chain	2.86	3.08	0.03	0.03

The seven most required fundamental competences of logistics and supply chain manager in the Republic of Serbia are: basics of information systems and technologies (IST) with special focus on spreadsheets and data bases, communication, planning and organizing of tasks, foreign languages, team work, solving problems and continuous learning (Table 3). The least required fundamental competence is math and statistics, according to data. The statistically significant difference was not found between the percentages of ads in which the specified fundamental competence has at least one occurrence in 2014 and 2017 (Wilcoxon signed-rank test: N=14; Z=-0.94; p=0.925). Also, the difference was not found in relation with indicator M_k of fundamental competences of logistics and supply chain manager (Wilcoxon signed-rank test: N=14; Z=-0.944; p=0.345).

Table 3. Indicators of fundamental competences of logistics and supply chain manager

Fundamental competences	P_k **[%]**		M_k **[1]**	
Empirical study	**2014.**	**2017.**	**2014.**	**2017.**
Basics of IST (special focus on spreadsheets and data bases)	80.00	93.85	0.91	1.40
Communication	88.57	92.31	2.00	2.63
Planning and organizing of tasks	82.86	89.23	2.14	3.15
Foreign languages	82.86	89.23	1.09	1.26
Team work	77.14	80.00	1.17	1.32
Solving problems	62.86	63.08	0.91	1.09
Continuous learning	45.71	52.31	0.97	0.86
Leadership	34.29	49.23	0.71	0.86
Interpersonal skills	77.14	49.23	1.66	0.83
Decisions making	42.86	30.77	0.49	0.49
Business management	57.14	23.08	0.71	0.31
Integrity	22.86	23.08	0.31	0.23
Project management	22.86	21.54	0.31	0.42
Math and statistics	22.86	4.62	0.23	0.05

4.1 Discussion of results

This is probably the first longitudinal study of logistics and SCM job ads which is conducted in the Republic of Serbia. Results of this study are attractive because they are derived from the real requirements of employers for the logistics and SCM professionals. However, some of the limitations of this longitudinal study should be noted. First, this study is limited to one developing country – the Republic of Serbia. Second, the study is limited to the two time intervals in 2014 and 2017, and one source of logistics and SCM job ads. Another limitation of this study is that all logistics and SCM job ads are considered without making difference between entry-level logistics jobs, senior logistics managers, supply chain managers, procurement managers, supply chain planers and analysts, and humanitarian logisticians (see e.g. Murphy and Poist, 1991, Giunipero and Pearcy, 2000, Gammelgaard and Larson, 2001, Razzaque and Sirat, 2001, Murphy and Poist, 2006, Flöthmann et al., 2018). Also, in this study the difference regarding size of companies was not considered (see e.g. Wagner et al. 2018).

The results show that employers expect candidates with university bachelor's degree and relevant work experience. In some cases, they are open for candidates with other school qualification and extensive relevant work experience (Cvetić et al., 2017, Cvetić et al., 2018). Several other studies done in the United Kingdom and Germany, which have similar scope, also emphasize the importance of relevant work experience and the ability of fast understanding processes in supply chain (Cacciolatti and Molinero, 2013; Kotzab and Wünsche, 2015). Derwik et al. (2016) indicated that work experience is very important for logistics and SCM professionals (p. 4824). Kotzab et al. (2018) pointed out that work experience was required for almost all logistics and SCM job open positions in Germany. Kotzab and Wünsche (2015) went further and emphasized that relevant work experience is 'the most important qualifier for an employment position in logistics' and supply chain management field (p. 517).

The most required professional competences of logistics and supply chain manager in the Republic of Serbia are: performance management, customer relationship management, demand forecasting and inventory management, warehouse management, supplier relationship management, transportation management, and distribution management (Table 2). These outcomes might be compared with findings of two studies done in the US and Brazil (Sodhi et al., 2008; Campos et al., 2019). Thus, Sodhi et al. (2008) found that sourcing and supplier management, inventory and forecasting, marketing and channel restructuring, and metrics and performance (that can be related to supplier relationship management, demand forecasting and inventory management, customer relationship management and performance management) are very important skills to US employers. On the other side, these researchers found that product design and new product introduction, and location and supply chain design (that can be related to product introduction into the market and designing supply chain) are among the least demanded competences. Furthermore, Campos et al. (2019) indicated that very important specific competences for SCM professionals in Brazil are: purchasing, inventory management, storage and handling, and demand and order processing.

As regards fundamental competences, a number of these competences are expected from logistics and SCM professionals (e.g. Cvetić et al., 2017, Cvetić et al., 2018; Bak et al., 2019) The fundamental competences, such as basics of IST, communication, planning and organizing of tasks, foreign languages (particularly knowledge of English), team work, solving problems and continuous learning, are among the most demanded from candidates in the Republic of Serbia. One of studies done in the US by Radovilsky and Hegde (2012) also put attention to basics of IST and communication, as the most demanded competences. Bak et al. (2019) put attention to soft skills of SCM professionals, and among others, found that communication, planning, initiative and negotiation are clearly quite important soft skills. Campos et al. (2019) indicated that the most important general competences for SCM professionals in Brazil are: ethical and moral posture, creative problem-solving, leadership, relationships, communication, budget and cost control, and information technology. A difference exists in the importance of foreign languages between Serbian, US and Brazilian employers. Employers in the US and Brazil don't see the importance of foreign languages (Murphy & Poist, 2006; Radovilsky & Hegde, 2012; Campos et al., 2019). The reasons are different. The US employers implied communication in English by default. The authors Campos et al. (2019) pointed out the importance of knowledge English language and find some kind of justification for their results, such as minimal international transactions in the case of mid-sized supermarkets in Brazil. The importance of foreign languages was also recognized by one study from Germany (Kotzab et al., 2018).

5. CONCLUSION

This longitudinal study tries to reinforce the outcomes of the two previous studies of logistics and SCM job ads conducted in the Republic of Serbia. The results are based on empirical data and reveal what competences logistics and SCM professionals need to have, develop and continually improve. The most required professional and fundamental competences of logistics and supply chain manager in the Republic of Serbia are identified. Although this study has some limitations it can be a good starting point for improving programmes, courses, trainings, certifications, occupational standards in the logistics and SCM field in the Republic of Serbia. In future, the empirical studies of this type should be repeated to make generalization of findings.

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SPATIAL COMPETITION WITH REGULATORY INTERVENTION

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Abstract: *A Competition model involves situations where two or more entities (companies) compete with the purpose of gaining market share. In a region with a certain spatial structure we consider spatial competition models, and such location-allocation models fall under the game theory. The paper focuses on modeling such a situation when two competing companies offer identical goods on the market, but the price of these goods may vary. These companies are deciding where to build their operations. The cost of the customer includes both the price of the goods and the transport costs. However, the regulator also enters into the game with a preference of a specific location in order to support a local economy, reduce negative environmental impacts, etc. As a result, customers can be divided into different groups. One group consists of myopic customers who only consider their own costs, whilst the second group includes customers who follow regulator recommendations and buy only in the preferred location. The third group consists of customers who change their behavior based on their maximum cost.*

Keywords: *Spatial competition, regulator preference, game theory*

1. INTRODUCTION

The paper is focused on location-allocation models that are parts of spatial competition models. We will model the location of two competing companies offering an identical product at different prices in a geographically determined market. The first known models are associated with the name of Hotelling (Hotelling, 1929). However, Hotelling considered the location along the line and we will extend these considerations by adding a spatial structure that can be described as a graph. We will further extend the model by situation where a regulator wants to actively intervene and prefer the operations at a particular location. Obviously, the regulator's preference does not always depend solely on economic benefits, but may be a purely political decision to support certain areas.

The easiest way to take into account node preference would be to regulate the price (some form of subsidy or penalty). However, we will consider also the company's awareness and suppose that some customers will follow the regulator's recommendation and buy at the preferred node, thereby increasing demand at that node. Thus, a society (consumers) can

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be divided into two groups. In the first case, consumers are considered to be myopic (short-sighted), that is, they are unaware of the damage that occurs when purchasing goods (and building an establishment) at a location other than the designated location. Such behaviour can cause negative externalities because of, for example, higher traffic loads, which causes higher pollution of the entire area and not just at a given location. If the regulator's preference for a given node is to support local manufacturers or suppliers, ignoring preferred nodes can have a negative impact on the economic situation of the entire region.

One of the major factors in preferred areas is the application of conscious zoning (Sequeira Lopez, 2018). Zoning is used as a way to isolate negative externalities (such as pollution) outside public areas or in the case of product (service) support in the preferred area (Pekár J. et all, 2012). On the other hand, customers who follow the recommendations of the regulator support the local economy and can also generate a lower negative impact on the environment.

The regulator assumes that the market will be divided among conscious and unconscious customers. In this case, conscious customers will buy in the preferred node. Demand of unconscious customers will be shared between the preferred and non-preferred node.

We will solve this situation within the game theory models and in the simplest case it is possible to formulate a game with a constant sum. Therefore, we will introduce the basic formalization of such a game.

2. TWO-PLAYER GAME WITH CONSTANT SUM

A two-player game with constant sum can be described as follows:

Let $P = \{1,2\}$ be a set of players. Each player has a finite set of strategies (X – player 1, Y – player 2}, i.e. player 1 chooses $\mathbf{x} \in X$, player 2 chooses $\mathbf{y} \in Y$, then $(x, y) \in X\text{x}Y$ is set of all results of the game $(x, y) \in X\text{x}Y$. The individual elements of the sets X and Y can be arranged by a finite number of non-negative numbers (elements of the set $X: i = 1,2, \ldots m$ and elements of the set $Y: j = 1,2, \ldots n$) and the results of the game for player 1 can be indicated in the matrix $\mathbf{A}_{mxn} = \{a_{ij}\}$, where a_{ij} indicates the player's payoff at the result (i, j). The values of the game for player 2 can be indicated in the matrix $\mathbf{B}_{nxm} = \{b_{ji}\}$, where b_{ji} indicates the player's payoff at the result (j, i). The constant sum can be characterized as follows: $\mathbf{B}_{nxm} = \mathbf{C}_{nxm} - \mathbf{A}^{\mathrm{T}}_{mxn}$, where $\mathbf{C}_{nxm} = \{c\}$ with c being the constant independent of the strategy choice.

The aim is to identify equilibrium strategies for both players. The status is defined as equilibrium, if the system has a tendency to remain in such state under certain conditions (only such set of strategies can be considered as a satisfactory result, if any effort to unilaterally violation automatically leads to damage to a player attempting to do so).

Game solutions are based on the following assumptions: Both players have complete information about the model of the conflict situation, i.e. they know the payoff matrix $\mathbf{A}_{mxn} = \{a_{ij}\}$, players are intelligent, i.e. the players want to maximize the payout and know that so does the opponent, the players are careful, i.e. they try to minimize the risk. The solution to the game results in identifying the equilibrium point in pure strategies (saddle point of matrix $\mathbf{A}$) or in mixed strategies (Chobot et al, 1991). (Goga, 2013), (Dlouhý, 2007).

The mixed strategy of player 1 is the m-dimensional vector $x, \sum_{i=1}^{m} x_i = 1, x_i \geq 0, i =\leftarrow V$ and the mixed strategy of player 2 is the n-dimensional vector$y, \sum_{j=1}^{n} y_j = 1, y_j \geq 0, j \leftarrow V$. Mixed strategies can then be identified using simple linear programming problem (Chobot et al, 1991).

3. SPATIAL COMPETITION MODEL WITH REGULATORY INTERVENTION

The spatial game is based on the following assumptions: Let $V = \{1,2, \dots n\}$ is a set of customers and let be given a finite continuous oriented edgewise-rated graph $G = (V, H)$, where V represents a non-empty n-element set of graph nodes, and $H \subset VxV$ represents a set of edges $h_{ij}, i, j \in V$ from the i-th to j-th., with each oriented edge h_{ij} being assigned a real number $o(h_{ij})$ called a valuation or also the edge value of h_{ij}. The network game is formulated in a so-called complete or a complete weighted graph $\bar{G} = (V, \bar{H})$ with the same set of nodes as graph G, where $\bar{H}$ is the set of edges between each pair of nodes i and j, their valuation being equal to the minimum distance between the nodes i and j in the original graph $i, j \in V$. If d_{ij} represents the minimum distance (the shortest path length) between nodes i and j, then the matrix $\mathbf{D}_{nxn} = \{d_{ij}\}$ is the shortest distance matrix.

Let´s assume two companies (players), $P = \{1,2\}$ offering a homogeneous product (goods or service) that have the ability to build their operations in one of the nodes of graph $\bar{G}$. Suppose the nodes of graph also represent the seat of the customers with constant demand. Although both players offer an identical product in an unlimited amount, the product price is different. Let us denote $p^{(1)}$ the product price for player 1 and $p^{(2)}$ the product price for player 2. We do not consider any capacity limitations; every customer can buy a product at any company. Customers, however, take into consideration the total price of the product consisting of both the purchase price of the product and the price of the transport to a chosen company. Transport costs are rated as t/unit of distance. The aim is to identify those nodes in which companies build their operations, assuming mutual interaction, and it is known that customers always prefer lower cost purchases (in case of equal costs, companies will split demand in half). The model taking into account the above assumptions was presented in (Sequeira Lopez & Čičková, 2018). In this way, the cost of the consumer of purchasing at company 1 can be written in a matrix $\mathbf{N}^{(1)} = \{n_{ij}^{(1)}\}, i, j \in V$ with elements are defined as follows:

$$n_{ij}^{(1)} = t * d_{ij} + p^{(1)}, i, j \in V \quad (1)$$

Analogical for the player 2 we specify the matrix $\mathbf{N}^{(2)} = \left\{n_{ij}^{(2)}\right\}, i, j \in V$:

$$n_{ij}^{(2)} = t * d_{ij} + p^{(2)}, i, j \in V \quad (2)$$

Now, consider the influence of the regulator, which aims to actively increase interest in a particular node. The models are further expanded to include situations where the regulator wants to actively disable or reduce consumption at a specific node. The regulator may interfere by affecting the price at a given node through a fine or penalty at the node where the location of the establishment is undesirable from its perspective. Thus, the total cost to the consumer at a given node is increased, provided that the company takes these measures into account in the price of the product, that is, they increase the product price by the amount of the regulator's sanction.

Let´s introduce a parameter $\lambda \in (0,1)$ that represents awareness of the society. It means that λ % of the society will be aware and will follow the preferences of the regulator (will purchase in preferred location) regardless its own costs. Let´s denote a preferred location as $pref \in \{1,2,\dots n\}$. Then, the myopic consumers are represented by $1-\lambda$.

Then it is possible to define the elements of the payoff matrix of player 1 ($\mathbf{A}$) in the form of the following pseudo code:

SET PAREMETERS $V = \{1,2,\dots n\}, \boldsymbol{D}_{nxn} = \{d_{ij}\}, i,j \in V\ , t, p^{(1)}, p^{(2)}, \lambda \in (0,1),$

$pref \in V$

DECLARE $N_{n*n}^{(1)} = \left\{n_{ij}^{(1)}\right\}, i,j \in V;\ A_{n*n}\{a_{ij}\}, i,j \in V;$

LOOP $(i,j\ \in V)$ **DO**

$n_{ij}^{(1)} = t * d_{ij} + p^{(1)};$

$n_{ij}^{(2)} = t * d_{ij} + p^{(2)};$

$a_{ij} = 0;$

LOOP $(k,i,j\ \in V)$ **DO**

IF $n_{ki}^{(1)} <\ n_{kj}^{(2)}$ **and** $i = pref$ **DO**$a_{ij} = a_{ij} + 1;$

ELSEIF $n_{ki}^{(1)} <\ n_{kj}^{(2)}$**and** $i \neq pref$ **DO**$a_{ij} = a_{ij} + (1-\lambda);$ (3)

ELSEIF $n_{ki}^{(1)} >\ n_{kj}^{(2)}$ **and** $j = pref$ **DO**$a_{ij} = a_{ij} + \lambda;$

ELSEIF $n_{ki}^{(1)} =\ n_{kj}^{(2)}$ **and** $j = pref$ **DO**$a_{ij} = a_{ij} + \lambda + 0{,}5(1-\lambda);$

ELSEIF $n_{ki}^{(1)} =\ n_{kj}^{(2)}$ **DO**$a_{ij} = a_{ij} + 0.5;$

ENDIF

Obviously, under the given assumptions, it is possible to formulate a game with a constant sum, where the constant of the game $c\ =\ n$ (since players share a constant demand of n nodes) and elements of matrix $\mathbf{B}$ can be calculated as $\mathbf{B}_{nxn} = \mathbf{C}_{nxn} - \mathbf{A}_{nxn}^{\mathrm{T}}$, where $\mathbf{C}_{nxn} = \{c\}$.

Now, consider the maximum difference cost that the consumer is willing to spend on the goods. Let´s denote such maximum difference cost as T_{MAX}. Then, the demand is shared between the preferred and non-preferred node based on maximum difference costs, and the conscious consumer will also shop at the non-preferred node if the total preferred node purchase cost exceeds T_{MAX}.

Then it is possible to define the elements of the payoff matrix of player 1 ($\mathbf{A}$) in the form of the following pseudo code:

SET PAREMETERS $V = \{1,2,\dots n\}, \boldsymbol{D}_{nxn} = \{d_{ij}\}, t, p^{(1)}, p^{(2)}, \lambda \in (0,1), pref \in V, T_{MAX}$

$N_{n*n}^{(1)} = \left\{n_{ij}^{(1)}\right\}, i,j \in V;\ A_{n*n}\{a_{ij}\}, i,j \in V;$

LOOP $(i,j\ \in V)$ **DO**

$n_{ij}^{(1)} = t * d_{ij} + p^{(1)};$

$n_{ij}^{(2)} = t * d_{ij} + p^{(2)};$

$a_{ij} = 0;$

LOOP $(k, i, j \ \in V)$ **DO**

IF $n_{ki}^{(1)} < n_{kj}^{(2)}$**and** $= pref$ **DO** $a_{ij} = a_{ij} + 1;$

ELSEIF $n_{ki}^{(1)} < n_{kj}^{(2)}$**and** $i \neq pref$

and $\left(n_{kj}^{(2)} - n_{ki}^{(1)}\right) \leq T_{MAX}$**DO** $a_{ij} = a_{ij} + (1 - \lambda);$ (4)

ELSEIF $n_{ki}^{(1)} > n_{kj}^{(2)}$ **and** $i = pref$

and $\left(n_{ki}^{(1)} - n_{kj}^{(2)}\right) \leq T_{MAX}$ **DO** $a_{ij} = a_{ij} + \lambda;$

ELSEIF $n_{ki}^{(1)} = n_{kj}^{(2)}$ **and** $j = pref$ **DO**$a_{ij} = a_{ij} + \lambda + 0{,}5(1 - \lambda);$

ELSEIF $n_{ki}^{(1)} = n_{kj}^{(2)}$ **DO** $a_{ij} = a_{ij} + 0.5;$

ENDIF

In the next section, we will illustrate this approach by solving illustrative examples.

4. EXAMPLES

Let's assume the existence of five potential customers $V = \{1,2,3,4,5\}$, each of them is located in the unique node of a graph G. We also assume the form of a duopoly market where each of the companies can build a branch office in any node of this graph $i \in V$. Each player (company) aims to maximize the number of nodes that are served. Although both players offer a homogeneous product, its price is $p^{(1)} = 1$ for player 1 and $p^{(2)} = 1.1$ for player 2. Let consider the following weighted graph in figure 1:

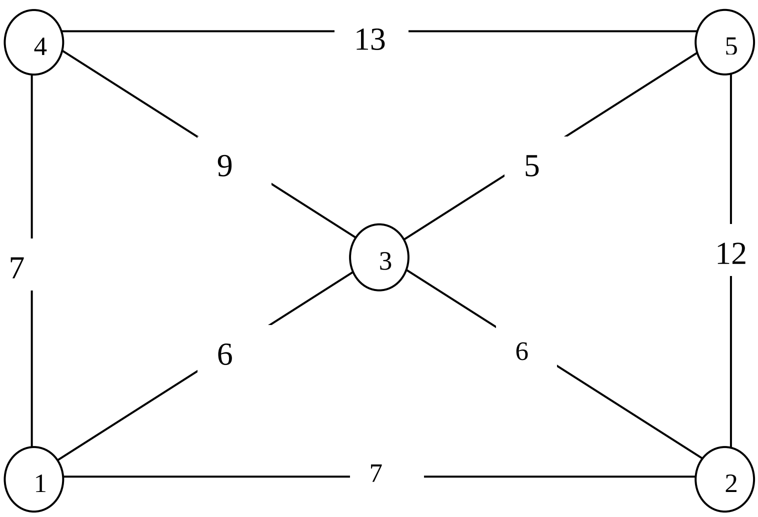

Figure1. Graph of distances between nodes

Let the shortest distance matrix $\mathbf{D} = \{d_{ij}\}, i, j \in V$ between all the nodes of the network are represented by the shortest distance matrix for ours five nodes.

$$\mathbf{D} = \begin{bmatrix} 0 & 7 & 6 & 7 & 11 \\ 7 & 0 & 6 & 14 & 11 \\ 6 & 6 & 0 & 9 & 5 \\ 7 & 14 & 9 & 0 & 13 \\ 11 & 11 & 5 & 13 & 0 \end{bmatrix}$$

We assume unit transport costs $t = 1$, Let´s suppose the regulator prefers the node 3, let's say the parameter $\lambda \in (0,1)$ is 0.4, i.e. 40% of the population will follow the regulator strategy. Based on (1) and (2) it is possible to quantify matrix elements $\mathbf{N}^{(1)}$ and $\mathbf{N}^{(2)}$ as follows:

$$\mathbf{N}^{(1)} \begin{bmatrix} 1 & 8 & 7 & 8 & 12 \\ 8 & 1 & 7 & 15 & 12 \\ 7 & 7 & 1 & 10 & 6 \\ 8 & 15 & 10 & 1 & 14 \\ 12 & 12 & 6 & 14 & 1 \end{bmatrix} \text{ and matrix } \mathbf{N}^{(2)} \begin{bmatrix} 1.1 & 8.1 & 7.1 & 8.1 & 12.1 \\ 8.1 & 1.1 & 7.1 & 15.1 & 12.1 \\ 7.1 & 7.1 & 1.1 & 10.1 & 6.1 \\ 8.1 & 15.1 & 10.1 & 1.1 & 14.1 \\ 12.1 & 12.1 & 6.1 & 14.1 & 1.1 \end{bmatrix}$$

We assume the regulator set the same weight to all other nodes (3), i.e. the node 4 will be tree time more attractive for the followers of the regulator.

If we do not consider lost demand, it is possible to quantify the elements of matrix **A** for player 1 as follows:

$$\mathbf{A} = \begin{bmatrix} 3 & 2.4 & 1.2 & 2.4 & 1.8 \\ 1.8 & 3 & 0.6 & 2.4 & 1.2 \\ 3.8 & 4.4 & 5 & 4.4 & 4.4 \\ 0.6 & 1.2 & 0.6 & 3 & 1.2 \\ 1.2 & 1.8 & 0.6 & 1.8 & 3 \end{bmatrix}$$

Since matrix **A** has a saddle point, there is only one solution to the game. The strategy of player 1 is represented by the vector: $\mathbf{x}^{(0)} = (0; 0; 1; 0; 0)$, i.e. the player 1 should invest in node 3 as the regulators prefers. The strategy of the player 2 is represented by the vector $\boldsymbol{y}^{(0)} = (1; 0; 0; 0; 0)$. As we can see, the player 2 in reaction of the action of player 1 should invest in node 1.

Obviously, the constant of this game is $c = 5$, the value of the game is 3.8 for player 1 (3.8 serviced nodes) and the value of the game for player 2 is $\mathrm{c} - 3.8 = 5 - 3.8 = 1.2$ (3 serviced nodes).

As a result, we can conclude that if the player 1 invests all capital in node 3 following the strategy of the regulator, he could take 3.8 node of five.

Let´s set maximum purchase price differences of the product $\mathrm{T}_{\mathrm{max}} = 1$. The calculations are based on (4). In such case, if the total price (transport cost and product price) is lower or equals to 2 MU, and the player 1 is located in preferred node, the player 1 takes all demand from the preferred node plus $\lambda \in (0,1)$ of other nodes. In our case, the awareness level is $\lambda = 0.4$. It means that 40 % of all nodes follow the regulator and purchase in preferred node. On the other hand, if the player 1 is located in any node other than the preferred one and the total price differences is lower or equals to 1 MU, the player 1 only takes $1 - \lambda$ of the demand of such node.

The regulator prefers the node 3 as in previous example and we assume that $\lambda \in (0,1)$ is 0.40.

Preserving the previous prepositions matrix **A** is as follows:

$$\mathbf{A} = \begin{bmatrix} 3 & 1.2 & 0 & 0 & 0 \\ 1.2 & 3 & 0 & 0 & 0 \\ 3 & 4 & 5 & 4 & 4 \\ 0 & 0.6 & 0 & 3 & 0 \\ 0 & 0 & 0 & 0 & 3 \end{bmatrix}$$

Since matrix **A** does not have a saddle point, we search for a solution to the game in mixed strategies. The mixed equilibrium strategy of player 1 is represented by the vector: $\mathbf{x}^{(0)} = (0.25; 0; 0.75; 0; 0)$, i.e. the player 1 should invest in node 3, (around 75% in this location), the other good investment could be in node 1 with 25%. The reaction of the player 2 is represented by the vector $\mathrm{y}^{(0)} = (1; 0; 0; 0; 0)$ as we can see; the player 2 in reaction of the action of player 1 should invest in node 1. The value of the game is 3 for player 1 (3 serviced nodes) and value of the game for player 2 will be $c - 3 = 5 - 3 = 2$. (2 serviced nodes).

As we can see in this illustrative example, the participation of the regulator changes the strategy of player 1 and has an impact on the value of the game. In examples above we assumed unit demand. In case the calculations are extended to include real demand represented by the number of people living in a specific area, the impact of the regulator´s preferred node of the network will be more significant. By adding a parameter of different demand in various nodes, the game would change to a non-constant sum game. Solving such types of games can be found in (Čičková & Zagiba, 2018)

The games are formulated as a linear programming problem solved with GAMS (solver CONOPT 3 24.9.2 r64480).

5. CONCLUSION

Game theory can be used to solve them specific problem of spatial competition. Our paper is focused on the case where a regulatory entity is involved in the game. The problem is formulated for duopoly (on the supply side). The issues are analyzed in the transport network with individual buyers located in the individual nodes of such network. The sellers decide on their position while trying to respect the behavior of buyers who minimize both the costs associated with the transport price and the transport costs. The buyers react to the strategy of the regulatory entity; in this case also the sellers are bound to follow that. It is obvious that if the level of follower of the regulatory entity is high enough, the sellers will set up their branches in the same nodes as preferred by the regulator. If that percentage decreases or is almost zero or there is not a regulator, it is the situation formulated in (Sequeira Lopez & Čičková, 2018). The GAMS professional software, which ranks among the powerful optimization computing environments, was used to solve the games mentioned above.

ACKNOWLEDGMENT

This work was supported by the project VEGA 1/0351/17 Application of Selected Models of Game Theory in Solving Some Economic Problems of Slovakia.

This paper is supported by the Slovak research and development agency, grant no. SK-SRB-18-0009 "OPTIMIZING OF LOGISTICS AND TRANSPORTATION PROCESSES BASED ON THE USE OF BATTERY OPERATED VEHICLES AND ICT SOLUTIONS".

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MODELING A HUMANITARIAN LOGISTICS INFORMATION SYSTEM'S PROCESSES AND INFORMATION NEEDS

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Abstract: *The purpose of this paper is to model the user requirements for an information system for the management of logistics processes of a humanitarian supply chain. The modeling procedure includes the development of the physical architecture as well asUML Diagrams. UML (Unified Modeling Language) is a standard language for specifying, visualizing, constructing, and documenting the artifacts of software systems.*

Keywords*: Humanitarian Supply Chain, Relief Logistics, Logistics Information Mnagement Systems, Information systems modeling*

1. INTRODUCTION

Humanitarian Logistics Management is the process of designing, implementing and controlling efficient / efficient product flow and storage, as well as, relevant information, from the point of origin to the point of consumption, in order to relieve people suffering after a disaster or disorder that affects the operation of a system causing extensive human, material, and environmental damage). In times of these disasters or disorders, the need for accurate and timely information is as crucial as is a rapid and coherent coordination among the international humanitarian community (European Commission, 2007).

Humanitarian Logistics Information Systems (HLIS) have the potential to enable better information sharing between organizations which can enhance the overall humanitarian operation (King, 2005). Effective humanitarian information systems that provide timely access to comprehensive, relevant and reliable information are critical to humanitarian operations.

The purpose of this paper is to model the key functionalities of a HLIS for the management of logistics processes of a humanitarian supply chain. The modeling procedure includes the identification of user requirements and the main modules, and the development of Unified Modeling Language (UML) diagrams. The information system under review is the main deliverable of the research program entitled: Integrated Operations Center for

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Providing Humanitarian Assistance (HELP), financed by the Interreg IPA Cross Border Cooperation Program "Greece - FYROM 2014-2020".

HELP’s main objective is the development of two (2) container business centers (a Command Center - C4I Mobile Container and a MEDICAL Treatment Container) to better coordinate and support logistics processes in the case of humanitarian aid. In other words to provide the right supplies to the right place, to the right people, the right time and the right amount as well as to coordinate and manage the resources available, provide a reliable business image and support decision-making.

2. HLIS’s KEY PARAMETERS

The examined system will accept a wide variety of input data from various sources such as, from: human resources, materials’ status, monitoring the allocation and use of resources, logistics equipment and tools, telecommunication tools amd platforms, tracking and motion detection systems, external events, etc., in order to disseminate via internet and present in a user-friendly format -in two-dimensional and three-dimensional- maps critical information needed to support the decision-making process.

The HLIS will have the ability to archive all aspects of a created events / incidents, so it becomes a powerful and adaptable tool for analyzing any response. Furthermore, what-if scenarios, statistics and reports will be easily generated and shared, that can impact future reresponse planning and execution. As such, it has tremendous utility across all echelons: tactical, operational, and strategic.

According to “Global Symposium +5”, the principles of humanitarian information systems are the following:

- Accessibility. Humanitarian information and data should be made accessible to all humanitarian actors by applying easy-to-use formats and by translating information into common or local languages. Information and data for humanitarian purposes should be made widely available through a variety of online and offline distribution channels including the media.
- Inclusiveness. Information management and exchange should be based on collaboration, partnership and sharing with a high degree of participation and ownership by multiple stakeholders including national and local governments, and especially affected communities whose information needs should equally be taken into account.
- Inter-operability. All sharable data and information should be made available in formats that can be easily retrieved, shared and used by humanitarian organizations.
- Accountability. Information providers should be responsible to their partners and stakeholders for the content they publish and disseminate.
- Verifiability. Information should be accurate, consistent and based on sound methodologies, validated by external sources, and analyzed within the proper contextual framework.
- Relevance. Information should be practical, flexible, responsive, and driven by operational needs in support of decision-making throughout all phases of a crisis. Data that is not relevant should not be collected.

- Impartiality. Information managers should consult a variety of sources when collecting and analyzing information so as to provide varied and balanced perspectives for addressing problems and recommending solutions.
- Humanity. Information should never be used to distort, to mislead or to cause harm to affected or at risk populations and should respect the dignity of victims.
- Timeliness. Humanitarian information should be collected, analyzed and disseminated efficiently, and must be kept current.
- Sustainability. Humanitarian information and data should be preserved, cataloged and archived, so that it can be retrieved for future use, such as for preparedness, analysis, lessons learned and evaluation. The use of Open Source Software should be promoted to further enhance access to information by all stakeholders in a sustainable way. When possible, post emergency data should be transitioned to relevant recovery actors and host governments.
- Reliability. Users must be able to evaluate the reliability and credibility of data and information by knowing its source and method of collection. Collection methods should adhere to global standards where they exist to support and reinforce credibility. Reliability is a prerequisite for ensuring validity and verifiability.
- Reciprocity. Information exchange should be a beneficial two-way process between the affected communities and the humanitarian community, including affected governments.
- Confidentiality. The processing of any personal data shall not be done without the prior explicit description of its purpose and will only be done for that purpose, and after prior informed consent of the individual concerned. Sufficient safeguards must be put in place to protect personal data against loss, unauthorized processing and other misuse. If sensitive information is publicly disclosed, the sources of such information will not be released when there is a reasonable risk that doing so will affect the security or integrity of these sources.

Moreover, the following table presents the functional requirements that the managers of the sample identify and assess:

Table 1. Classification and categorization of functional requirement

A	Assigning resources to disasters and dealing with emergencies.
	Provide operational status to all parties involved.
	Tracking and tracing of logistics equipment and tools.
	Telecommunication services (local and cloud).
	Tracking and motion detection systems (CCTV, detectors, sensors, alarms, etc.).
	Telecommunication platforms (fixed, satellite, GSM, radio, internet).
B	Real-time reporting on the state of road networks.
	Event management (display, import, modification, deletion).
	Show events on a digital map.
	Ability to present information to mobile phones.
	Provide all the information needed to support the decision-making process.
	Save event-related information in a digital geographic database.
	Ability and recording of business "what-if" scenarios.
	Ability to send individual and mass messages.
	Compatibility and integration with automated object recognition technologies (barcodes, rfid, etc.).
	Creating and managing disaster scenarios.
C	Manage communication and exchange of standardized messages.
	Present availability and operational status of available resources.
	Creation and management of business scenarios that are linked to the occurrence of natural disaster events or general events requiring the activation and support of decisions of the humanitarian logistics system.
	Providing real-time information on the state of the materials.
	Dynamic resource sharing.
	Display scenarios on a digital map by retrieving data from the database.
	Providing real-time information on the operational status of logistics equipment and tools.
	Presentation of geographic data in two-dimensional and three-dimensional maps.
	Monitoring the allocation and use of resources.

The discussion of the proposed system includes the identification of the modules, the description of the architecture and the key roles.

2.1 HLIS Modules

The information system's functionalities reference model consists of eight (8) modules as presented below:

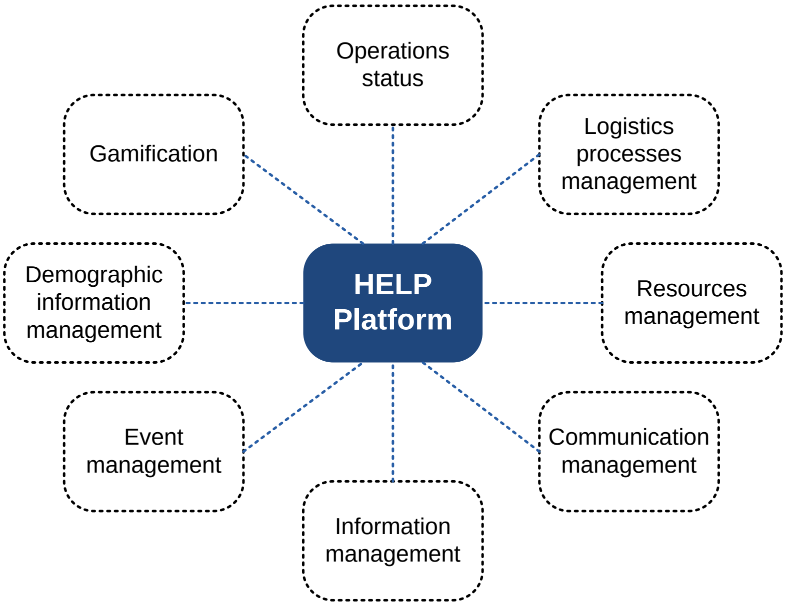

Figure 1. Information system's functionalities reference model

The modules and the corresponding functionalities are presented in the following table:

Table 2. Functional requirements of a HLIS of a humanitarian supply chain

Module	Functionalities
Operational status	• Create and deliver to all the involved parties the business image in real time and on a digital map. • Visualize (locate and detect) logistics infrastructure locations and provide additional operational status information of available resources and materials.
Logistics processes management	• Maintainng a supplier database and continually updating it, as well as, continuing training suppliers on how to act in a period of crisis to meet the required standards. • Selection of a route to optimize transport and distribution either direct (direct - direct transfer from the distribution center to the affected concentration points or indirect transfer via intermediate distribution centers). • Monitoring (for example, the knowledge of the location of the material in the supply chain - where it is located) and tracking (inventory of the previous points - how did it arrive?) of the materials. • Store and manage inventory for the immediate and satisfactory response to a disaster.
Resources management	• Inform about the availability and operational status of resources (such as water or food for immediate transport to the affected). • Assign resources to disasters and incidents. • Monitoring Assignment / Use of Resources. • Dynamic Resource Sharing. • Ability to interface with automated (auto) object recognition technologies (barcodes, QR codes, RFID)..
Communications management	• Telecommunication services (local, cloud). • Telecommunication platforms (fixed, satellite, GSM, radio, internet). • Integrated monitoring systems (CCTV, detectors, sensors, alarms, etc.).
Information management	• Provide all the information needed to support the decision-making process. • Geographic information system (GIS) capable of displaying 2D & 3D digital maps. • Geostrategic analysis. • Managing online communication and information exchange in the form of standardized messages. • Bulk or individual sending of messages.
Event management	• Creation of a new event (real-time or delayed), and their management (modification, deletion, etc.). • Link an event to the digital map and: ○ indicating an event on a digital map (google maps, etc.). ○ storing event-related information in a geographic digital information database. ○ recovery from this base. • Update real-time event display on Android, IoS, or Windows mobile devices, and Internet browsers, and retrieve information from the Geographic Digital Information Database.
Manage basic demographic information	• Example of grouping information include: age grouping, by region, other statistics - aggregated demographic data.
Gamification	• Creation and management of business scenarios that are linked to the occurrence of natural disaster events or general events requiring the activation and support of decisions of the humanitarian logistics system. • Display scenarios on a digital map by retrieving data from the geographic digital information database. • Ability to record and maintain business what-if scenarios. • Manage scenario reports (predefined - adhoc).

2.2 Architecture

The above system will be a Command and Control (C2) architecture of at least 3 levels of multi-level architecture (Web n-tier):

- Client tier / presentation tier / User Interaction will refer to the end-user interface and the presentation of the data. User access to the services available will be through a single technology platform, which will provide the user with identification, personalization and authorized access capabilities.
- The application / business logic tier application layer, which integrates business logic, that is, all business rules that govern the operation of each application.
- The data tier, which is responsible for storing data. It concerns information storage and management systems, whether it concerns transactional data, master data, or aggregate data. Application layer subsystems should be able to share common data models and shared data infrastructure.

2.3 Roles

The final users (actors) of the proposed HLIS are:

- System Administrator: This is the role reserved for MIS administrator.
- GIS Administrator: This is an individual that works with GIS databases and has been assigned the duties of uploading data layers as appropriate for given incidents as well as general use.
- Organization Administrator: This is the individual (or group of individuals) that manages that organization's membership in MIS, keeps contact information up-to-date, and supervises orientation and training of MIS. Potential organizations are the following key target groups of users of the proposed MIS:
    - Different levels of Civil Protection
    - Representatives of all the local, regional, and municipal authorities in the eligible areas
    - Army
    - Fire Department
    - Emergency medical centers
    - Local, regional, national, European, but also specialized mass-media, which contribute to the promotion of the Programme in the eligible areas
    - Civil Protection and Crisis management policy makers.
- Field team leaders: Individuals or group of individuals that gather, insert operational information and share information with others.

3. UML DIAGRAMS

The purpose of this paper is to model the user requirements for an information system for the management of logistics processes of a humanitarian supply chain. The modeling procedure includes the development of UML Diagrams. The Unified Modeling Language is a language for specifying, constructing, visualizing, and documenting the artifacts of a software-intensive system. Analogous to the use of architectural blueprints in the construction industry, UML provides a common language for describing software models, and it can be used in conjunction with a wide range of software lifecycles and development processes (Booch, Jacobson and Rumbaugh, 1999).

Two types of UML diagrams will be developed in this report:

- Use Case Diagrams, and
- Sequence Diagrams.

3.1 Use Case Diagrams

First, for each role that have been identified in the previous section, a use case diagram is developed to illustrate the functionalities of the proposed system. Use case diagrams are referred to as behavior diagrams used to describe a set of actions (use cases) that the proposed HLIS should or can perform in collaboration with one or more external users of the system (actors).

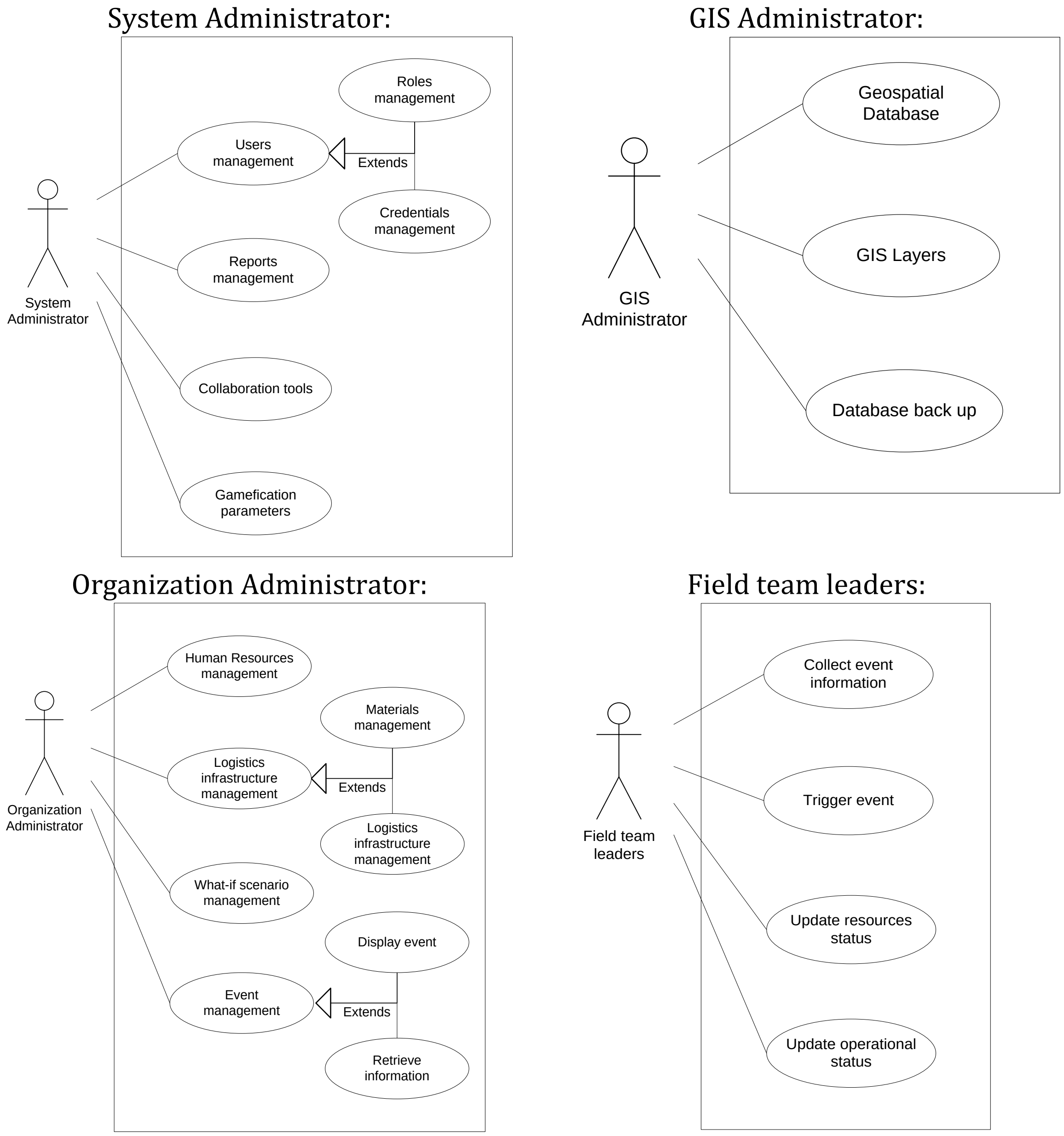

Figure 2. Use cases of HLIS

3.2 UML Sequence Diagrams

Moreover, a sequence diagram that involves three of the four roles is provided below to describe interactions among them in terms of an exchange of messages over time and to visualize and validate the event hanling scenario.

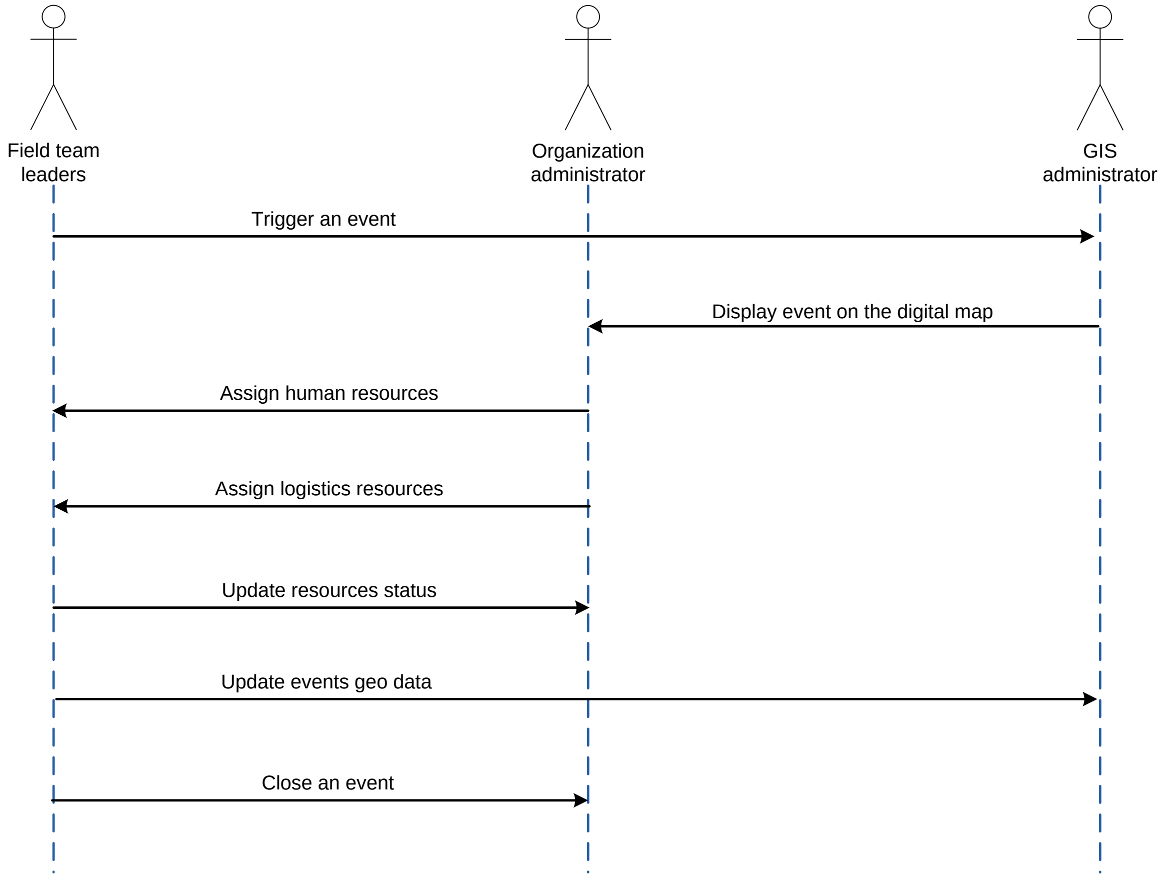

Figure 3. HLIS Sequence diagram

4. CONCLUSIONS

As reported in the Pamela Steele Associates Ltd (PSA) report entitled "Humanitarian supply chain information systems: insights for successful implementation", although each of the parties involved in a humanitarian supply chain uses innovative IT and telecommunication solutions, solutions have not been developed will coordinate these members (PSA, 2015). One reason for this paradoxical phenomenon is the fact that supply chains are still not seen as a critical success factor in a humanitarian aid program (Blansjaar and van der Merwe, 2014).

In recent years, several technological solutions have been developed, such as Helios IP funded by the renowned Fritz Institute. This system has been adopted by major humanitarian organizations such as Save the Children International, World Vision International and Care USA (Blansjaar and van der Merwe, 2014). However, the cost of purchasing and maintaining such a solution is very high especially for the regions that will support the HELP project. An appreciation of the project team is the acquisition of a more flexible and economical technological solution.

Functional requirements capture the intended behavior of the examined HLIS system. This behavior for the focused MIS for the humanitarian logistics system may be expressed as services, tasks or functions the system is required to perform. Use cases are useful in capturing and communicating functional requirements, and as such they play a primary role in product definition. An architecturally relevant subset of the use cases for each of the products to be based on the architecture also plays a valuable role in architecting. They direct the architects to support the required functionality, and provide the starting points for sequence diagrams that are helpful in component interface design and architecture validation.

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ECONOMIC IMPACTS OF SECA REGULATION ON MARITIME COMPANIES IN THE BALTIC SEA REGION – LITERATURE REVIEW AND LOW EMISSIONS RECOMMENDATIONS: PART 1

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Abstract: *The Intergovernmental Panel on Climate Change (IPCC) has stated that climate change is a major ongoing process requiring strict restrictive actions on a global level. This paper focuses on literature covering the impacts of the Sulphur Emission Control Area (SECA) based on academic papers published in 2017–2018. In numerous studies conducted before 2015, it was predicted that regulation would have serious impacts on maritime businesses. This is the first part of our research introducing the topic. The paper continuous in Part 2.*

Keywords*: Literature, SECA, Impacts.*

1. INTRODUCTION

There are a large number of published high quality papers addressing a deep concern regarding climate change. The Intergovernmental Panel on Climate Change (IPCC) (2018) calls forth significant global actions. Similarly, the European Commission (EC) (2011; 2018) has stated that by 2050, greenhouse gases (GHG) should be reduced to a level that is 60% of the 1990 level. The International Maritime Organization (IMO) (2014) and the European Parliament (EP) (2005; 2012) have declared that sulphur emissions in the maritime sector should be lowered in Europe. This was not voluntary environmental action, but based on international agreements, because voluntary reductions are not widely adopted or working (Broadstocka 2018). The Sulphur Emission Control Area (SECA) concerns all shipping companies operating in the Baltic Sea and in a part of the North Sea. The SECA regulation came into effect 1st January 2015. Vessels operating in the SECA region are not allowed to use fuel with a sulphur content exceeding 0.1%. The reasoning and philosophy behind this regulation is that (polluting) companies are not voluntarily limiting their emissions (Makkonen & Inkinen 2018). However, according to Linder (2018), external pressures such as community concerns regarding emissions and threats are also important in initiating voluntary restrictive actions and they may even be more important than the financial incentives. Global pollutant reductions in the maritime business sector also require compulsory environmental regulations based in

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international agreements. The challenge in achieving global agreements is that these regulations have significant impacts on current business environments and business models.

Traditionally, ships use fuel oil propulsion. Fuel oil can have a sulphur content of up to 3.5%. In comparison, the sulphur content of fuels used in trucks or passenger cars must not exceed 0.001%. Sulphur dioxide emissions from ships' combustion cause acid rain and generate fine dust. This can lead to respiratory and cardiovascular diseases and reduce life expectancy in the European Union (EU) by up to two years. The 2012 revision of the Sulphur Directive was designed to reduce the emissions of this air pollutant by setting maximum sulphur content levels for marine fuels. It also incorporated new standards set by the IMO into EU legislation – notably the 0.1% sulphur in fuel limit applicable in the SECAs. In 2016, the IMO made the landmark decision to maintain 2020 as an entry-into-force date of the global 0.5% sulphur cap, similar to Europe (i.e. in all sea waters outside SECAs, see EC 2018).

The aim of this study is to examine, based on research literature, how the economic impacts of SECA were studied from different industrial perspectives in research papers published in the Baltic Sea region. Before 2015, experts presented several anticipatory calculations which suggested that high prices of marine diesel oil would have serious impacts on maritime transport costs and the whole maritime industry (e.g. EMSA, 2010; Trafi 2013; Hämäläinen 2014). In Finland, maritime logistics costs in heavy industries often exceed 10% of turnover (Hämäläinen 2011). Therefore, all companies in the logistics chain are actively monitoring the way environmental regulations influence their economics.

Due to the SECA decision made by the EC, air polluting sulphur oxides (SOx) have substantially decreased over the past years. This is the result of joint efforts by Member States and the maritime industry in implementing the new EU rules on cleaner shipping fuels. The lower sulphur emissions will improve the lives of citizens living in the SECA regions even in the short term. Gallo et al. (2016) argue that the voluntary environmental market has led to the slow spread of voluntary emission reduction projects developed by local authorities in the EU, despite their high potential. New and stricter environmental regulations are expected to obligate companies to improve their product development processes. This may lead to the utilization of ideas produced by innovative (or disruptive) actions, especially in those companies belonging to these specific industry clusters. Until polluting industries are regulated and transformed into cleaner actors, even down to the zero-level, various new ways of thinking are needed (Yigitcanlar & Inkinen 2019).

Psaraftis and Kontovas (2009) applied data from the IHS Fairplay database from 2007 (45.620 commercial ships accounted for) and stated in their study that container ships are the top CO2-emitters in the world fleet, thus impacting the global atmosphere negatively. Unlike other studies, the work focused on cruise ships rather than on cargo ships, because a cruise ship's operation profile is more variable during the trip. In the global supply chain, marine transportation (per ton/km) has been considered the most environmentally friendly method of transporting heavy and bulk freight. According to Lindstad et al. (2011), emissions can be reduced by up to 30% with a negative CO2 abatement cost per ton, if the existing fleet is replaced with larger vessels. Replacing old vessels may take as long as 25 years, so the reduction in emissions will be achieved gradually as the existing fleet is renewed. This assumption was based on the idea that

Heavy Fuel Oil (HFO) bunker fuels will be used in the future, but this may not happen, depending on the decisions made by the IMO (Marineinsight 2018).

These considerations motivate this study that assesses the academic literature focusing on emission control and businesses. This helps formulate the future models and their classifications used as measurement categories. The literature is classified and analysed in order to respond to the following main questions:

- How were the impacts defined and observed in the literature?
- How have business strategies adapted to SECA?
- Which low emission solutions is science proposing?

2. SELECTED STUDIES CONCERNING SECA BEFORE 2015: EXPECTED IMPACTS AND CONSEQUENCES

In his case study, Hämäläinen (2015) argued that the sulphur directive has direct impacts on the economy of the Nordic bulk industry. Additionally, Hämäläinen predicted that the impacts of the sulphur directive will vary heavily from market to market. In 2010–2014, the marine cluster community in the Baltic Sea Region (BSR) was concerned about the impacts of the SECA-regulation on their core businesses (such as freight transportation). However, due to falling oil prices since the beginning of 2015, these (feared) impacts were not realized. Still, the future impacts are a significant challenge in this oil dependent sector. New extra costs are difficult to cover without increasing customer prices. Due to the expected rising fuel costs, large shipping companies decided to order larger vessels in order to decrease the impact of bunker costs. Maersk ordered the new 18.000 TEU 'triple E' box ships, which would operate with less than 50% fuel consumption by using slower steaming in comparison to the average industry level. The slower speed, when combined with accurate weather data, enables voyage routings that produce significant cost and emission reductions (Lindstad et al., 2013). This may be expected, given the relatively high speeds of these vessels (20–26 knots) as opposed to those carrying bulk cargoes (13–15 knots), indicating a nonlinear relationship between the ship's speed, fuel consumption and emissions: when the ship's speed is reduced, fuel consumption and emissions are also reduced drastically. Lower speed can have important side benefits: cost reduction is one and the other is supporting a depressed market, in which shipping overcapacity is the norm these days. Slow steaming ships are sailing stocks. According to Yao et al. (2012), the fuel purchase location is an important variable in minimizing total bunker costs. Similarly, Psaraftis (2012) states that bunker price and market freight rate may influence route planning.

Several industries were concerned about the Marine Diesel Oil (MDO) price level from 2015 onwards. There were large variations in bunker price estimations. Notteboom (2011) anticipated that the price of MDO could increase anywhere between 25% and 200% by the year 2015. The European Maritime Safety Agency (2010) speculated in their study that the sulphur directive may cause the MDO prices to increase by as much as 60–70%. However, from 2015 onwards until present day, the bunker price has fallen dramatically, which saved both freight owners and maritime logistics from significant economic losses.

Due to environmental and health reasons, the IMO (2014) and the EP (2005; 2012) decided that sulphur emissions should be extensively lowered in European sea regions.

Therefore, SECA (stated by the IMO) can be considered as an environmental action that is expected to bring forth positive health impacts (also Svaetichin & Inkinen 2017). Latest climate studies suggest that fast changes are needed in order to achieve lower emission rates. International shipping accounts for approximately 2.2% of global CO2 and 2.1% of global GHG emissions. In 2012, global CO2 emissions were 35,640 Mtons and total shipping emissions were 938 Mtons, representing 2.6% of total emissions. Commercial marine operations in the SECA region produced about 40 megatons of CO2, which was approximately 4.6% of the global marine transportation. Comparing emission factors in the SECA region between ships (20 g CO2/ton-km) and road transport (62 g CO2/ton-km) (Cefig 2011), marine transportation can be considered more environmentally efficient.

The SECA regulation forced the whole maritime cluster to focus on environmental issues in the Baltic Sea area. The shipping companies were also forced to lower their SOx emissions. The primary solutions were to use either MDO or HFO and scrubber technologies. Later on, low (or even zero) sulphur solutions, such as Liquid Natural Gas (LNG), emerged. The SECA regulation's effects have been studied and analysed particularly in the BSR. The use of scrubbers and HFO also aided in the cost management control, even though scrubbers were largely seen as an unreliable old technology (e.g. Bruckner-Menchelli, 2009). Acciaro (2014) predicted that ships would use, to some extent, the more environmentally friendly LNG, but it will likely remain uncommon in the near future. Alhosalo (2013) showed based on collected data (surveyed personnel of a ship-owner) that 88% of the respondents believed their company was going to use MDO as bunker fuel starting from January 1st 2015. This is an example of anticipated cost increases in the BSR.

3. REMARK ON THE DATA COLLECTION METHODS

The following remarks are needed in order to present the collected data. The papers were collected from two well-known scientific reference databases, Science Direct (SD) and Web of Science (WoS). These two databases were selected because they are widely used and represent the academic publication journals and articles which are also peer reviewed before publication in a fairly comprehensive way. The paper search was done based on publication year (2017 and 2018, up to October) and using a query sentence "SECA, economic impacts" in the keyword search. This query produced a selection of 21 papers. It is likely that most of these papers were written and composed before the publication year. Also, the data sets applied in these papers were, to a large extent, collected before 2015. Empirical papers are, of course, always dependent on the data and its properties, defining what kind of output the analysis produces. However, it was estimated that even if the data may be missing relevant articles, the obtained collection of 21 papers is enough to give a good insight into the latest discussion concerning SECA's impacts on businesses. Empirical results will be presented in the Part 2 of the paper.

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ECONOMIC IMPACTS OF SECA REGULATION ON MARITIME COMPANIES IN THE BALTIC SEA REGION – LITERATURE REVIEW AND LOW EMISSIONS RECOMMENDATIONS: PART 2

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Abstract: *This is the second part of our research. Two publication databases were queried: Science Direct (SD) and Web of Science (WoS). The search query in these channels was performed using keywords "SECA, economic impacts" to investigate how SECA implications were studied for clean business development. Two main topic groups were discovered. The first group includes topics that focus on solving negative impacts (economy of maritime businesses); and the second group consists of topics that focus on the positive impacts on health and the environment, particularly in SECA port regions. After the screening process, the data included 21 papers that matched the query specifications. The decision was made to only use the most recent studies that were completed after 2015. The results indicate that ship owners and fuel producers can use various methods simultaneously to adapt to the SECA regulation.*

Keywords: *Literature, SECA, Impacts.*

1. EMPIRICS: THEMES, SUBJECTS AND FOCUS AREAS OF THE SELECTED PAPERS

The following empirical observations conclude our study started in Part 1. For this purpose, Table 1 covers article titles, main topics (defined by the authors), journals, impact factor (IF) of the journal, and the number of citations. Table 1 is sorted by the impact factor, the highest is the first. The list shows the thematic diversity of journals. All studied journals are high ranking, as they belong to these most appreciated catalogues. Additionally, only a few articles were published in low impact journals (no impact factor or less than 0.3). One interesting observation is that the maritime-related subjects have been published in multidisciplinary journals, as indicated by Table 1. The most general themes such as energy, the environment or cleaner production, are identifiable in the journal profiling. Research on these topics concerns several industries and stakeholders. The SECA regulation is an EU directive forcing maritime businesses to adapt to a new situation; the selected articles present a large arsenal of different ways that companies could comply with low emission requirements. The presented articles' themes cover the whole maritime sector, from refining industries through fuel maintenance to engine modifications. Approximately 30% of the articles are published in Transportation

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Research Part D. Citation volumes are still rather low, reflecting the fact that these papers were published recently. There are some papers that already have some citations (top is 8). In total, there are 51 citations to these papers. Alternative fuels are a major study field in terms of citations. There is a growing need to find alternative fuel options for ships to replace HFO and scrubbers or low sulphur marine diesel. LNG seems to be one popular and relevant option mentioned in discussions concerning low emission bunker.

Lower maritime emissions require new reliable and solid technological solutions. These in turn require radical innovations that are harmonized to operate in accordance with the older existing solutions. Thus, there is also an incremental element involved. One of the key questions is how to build scalable solutions and methods, so that the new applications can be completed and installed in vessels at reasonable costs, producing added value through their functionality. The scalability of the new solutions is not covered in these studied papers. On one hand, new clean bunker could be understood as a scalable environmental solution as such; and on the other, scrubber installations are more uniquely built and modified for every vessel in question and therefore scalability is difficult to verify.

Table 2 lists all the keywords obtained from the 21 papers. Keywords were unavailable for only one article. Each article contains a number of keywords that can be related to broader categories. As we can perceive, these articles discuss several topics from the perspectives of e.g. marine fuels, modelling, strategy, hinterlands and ports. These keywords clearly show that during these two years, SECA and its impacts have generated a diverse field of studies, presented in these scientific articles. The selection word “impact”, in itself, leads to mainly economic and environmental topics being prominent in these papers. Emission levels and the bunker type used have an interactive relation with each other. A significant amount of daily operating costs (25–60%) results from bunker consumption when ships are in operation. The emissions of the vessels mostly consist of CO2, SOx and NOx, as well as other discharges (e.g. black carbon, BC) from the burning. The keywords of the articles indicate that there is a significant amount of research addressing how SECA (and other environmental) regulations impact on the whole maritime business sector’s models and the maritime dependent supply chain.

The implementation of binding regulations causes modifications to the traditional maritime operation models. The SECA regulations have been studied quite extensively, as the maritime sector is a complicated business environment. From an environmental viewpoint, lower emissions will become a global norm. This requires fast and decisive action in every oil dependent industry sector, and the maritime and transportation industries must also act quickly in the coming years. Therefore, it is not surprising that both economic and environmental topics have been widely discussed in the presented articles. Emission regulations (on-shore or off-shore) and changes in technical solutions (change of fuel, scrubbers, new engines, or modifications of engines) onboard have an impact on profitability. Additionally, due to the complicated business situation and strong competition in the maritime supply chain market, estimated profits are probably declining. In all likelihood, new disruptive innovations (scalability should be included) currently under development may mitigate some of the negative economic factors.

The presented literature clearly demonstrates that researchers have revealed that companies are looking to find solutions from different angles and directions, using various technical solutions and business model methods. The papers also address the diversity of combinations of these solutions and methods. Generally, the papers agree that the road to a cleaner marine environment (and emission free shipping operations) is a project requiring knowledge from numerous disciplines and problem solving perspectives, creating a highly complex system, in which each part affects another. Traditionally, marine operations have not focused on emission regulations. Instead, their focus has been in creating a profitable business where environmental issues have been secondary concerns. Therefore, an important message from these papers is that on every level: the local, regional, national, European, and global levels, there is a crucial need for internationally agreed, strict environmental regulations that should be followed and monitored to ensure a fair competition environment. The articles strongly stress from many angles that the pollution levels should be reduced using all reasonable means. Investments should be focused on non-polluting technology.

In the near future, large environmental investments should also be made in the maritime sector. In order to demonstrate this need in accordance with the article contents. It includes the title, author and shortened version and main points of the abstract. The papers were sorted according to main topics as indicated in Table 1. Global environmental protection will affect, in the end, all emission-producing businesses. Normally, various economical resources are required for investments to get environmentally positive results. There are various ways to mitigate emissions at a reasonable cost, so that business remains profitable under stricter environmental regulations, such as SECA. The economic aspects are closely linked with environmental regulations and cleaner nature.

Table 1. Titles, authors, main topics, publishing journals, impact factors and citations

Titles	Author(s)	Main topics	Journals	If/Cit
Renewable methanol as a fuel for the shipping industry	Svanberg, M. (2017)	Economic Environmental Methanol	Renewable and Sustainable Energy Reviews 94 (2018) 1217–1228	If 9,18 Cit. 0
Evaluation of gas turbines as alternative energy production systems for a large cruise ship to meet new maritime regulations	Armellini, A. et al. (2018)	Technological Alternatives	Applied Energy 211 (2018) 306–317	If 7,90 Cit. 4
Environmental economics of lignin derived transport fuels	Svetlana V. Obydenkova, S. V. et al. (2017)	Economic Environmental Ethanol Plant	Bioresource Technology 243 (2017) 589–599	If 5,81 Cit. 6
How to recognize and measure the economic impacts of environmental regulation: The Sulphur Emission Control Area case	Lähteenmäki-Uutela, A. et al. (2017)	Environmental Socio-Economic	Journal of Cleaner Production 154 (2017) 553-565	If 5,65 Cit. 1
Sectoral and technological systems of environmental innovation: The case of marine scrubber systems	Makkonen, T. and Inkinen, T. (2018)	Environmental Product Innovations	Journal of Cleaner Production 200 (2018) 110-121	If 5,65 Cit. 0
The development and comparison of CO_2 BOG re-liquefaction processes for LNG fueled CO_2 carriers	Byeong-Yong Yoo, B-Y. (2017)	Economic Alternative Fuel Systems	Energy 127 (2017) 186-197	If 4,97 Cit. 5
The activity-based methodology to assess ship emissions - A review	Nunes, R.A.O. et al. (2017)	Environmental Health	Environmental Pollution 231 (2017) 87-103	If 4,36 Cit. 6
Explaining choices in energy infrastructure development as a network of adjacent action situations: The case of LNG in the Baltic Sea region	Gritsenko, D. (2018)	Alternative Fuels Emissions Governance	Energy Policy 112 (2018) 74–83	If 4,04 Cit. 4

Table 1. Titles, authors, main topics, publishing journals, impact factors and citations - continued

Titles	Author(s)	Main topics	Journals	If/Cit
A chemometric investigation of aromatic emission profiles from a marine engine in comparison with residential wood combustion and road traffic: Implications for source apportionment inside and outside sulphur emission control areas	Czech, H. et al. (2017)	Environmental Health	Atmospheric Environment 167 (2017) 212-222	If 3,71 Cit. 1
The costs and benefits of a nitrogen emission control area in the Baltic and North Seas	Åström, S. et al. (2018)	Economic NECA Health	Transportation Research Part D 52 (2017) 185–201	If 3,45 Cit. 4
The impact of alternative routing and packaging scenarios on carbon and sulphate emissions in international wine distribution	Harris, I. et al. (2018)	Economic Health Environmental Emissions	Transportation Research Part D 52 (2017) 303–321	If 3,45 Cit. 0
The implications of the new sulphur limits on the European Ro-Ro sector	Zis, T. and Psaraftis, H. N. (2017)	Economic Environmental Modelling	Transportation Research Part D 55 (2017) 162–174	If 3,45 Cit. 8
A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements	Schipper, C. A. et at. (2017)	Economic Environmental KPI Sustainability	Transportation Research Part D 57 (2017) 84–111	If 3,45 Cit. 1
Marpem: An agent-based model to explore the effects of policy instruments on the transition of the maritime fuel system away from HFO	Bas, G. et al. (2017)	Emissions Alternative Fuel Systems	Transportation Research Part D 58 (2018) 261–279	If 3,45 Cit. 1
A global review of the hinterland dimension of green port strategies	Gonzalez, M. et al. (2018)	Environmental Performance Hinterland	Transportation Research Part D 59 (2018) 223–236	If 3,45 Cit. 1
A multiple ship routing and speed optimization problem under time, cost and environmental objectives	Wen, M. et al. (2017)	Economic Freight Costs Modelling	Transportation Research Part D 52 (2017) 303–321	If 3,45 Cit. 8
Health costs and economic impact of wind assisted ship propulsion	Ballini, F. et al. (2017)	Economic Health Health-Economic	Ocean Engineering 146 (2017) 477–485	If 2,21 Cit. 1
Maritime energy contracting for clean shipping	Olaniyi, E. O. et al. (2018)	Costs Investments Innovation	Transport and Telecommunication Journal MAR 2018	If 1,54 Cit. 1
Towards EU 2020: An Outlook of SECA Regulations Implementation in the BSR	Olaniyi, E. O. (2017)	Comply SECA Approaches Economic	Baltic Journal Of European Studies 7 (2) Oct 2017	If N/A Cit. 4
The impact of environmental regulations on regional development in Eastern Estonia	Prause, G. and Olaniyi, E. O. (2017)	Shale Industry Oil Refinery Socio-Economic Business Development	New Challenges Of Economic And Business Development - 2017: Digital Economy 461-472	If N/A Cit. 0
Strategic Energy Partnership in Shipping	Olaniyi, E. O. et al. (2018)	Strategic Energy Partnerships Scrubber Technology	Reliability and Statistics In Transportation And Communication (Book) Oct 18-21, 2017	If N/A Cit. 0

Table 2. Keywords of the articles.

IMO Cruise ship Emissions Optimization Gas turbines	Effectiveness of regulation Regulatory impact assessment Environmental regulation Maritime industry Sulphur Exhaust gas emissions Shipping	Ship speed optimization Multi-commodity pickup and delivery Branch-and-price Combined ship speed and routing
REMPI IVOC Heavy fuel oil Marine gas oil PAH	Environmental innovation Marine scrubber system Maritime industry Sectoral system of innovation Technological system of innovation	Agent-based modelling Liquefied natural gas Maritime fuels Policy evaluation Simulation Sulphur emissions System perspective
Clean shipping; Emission reduction Envisum project Eu 2020 Institutionalism SECA	SECA Regulations Business models Entrepreneurship Clean shipping Strategic Management	Port Port-city Sustainability Assessment Methodology Key performance indicator
2G ethanol plants Lignin Fuels Life cycle assessment	Wind assisted ship propulsion Health economic externalities Air pollution EVA model	International freight transport Wine port/node/route selection CO2e reduction Sulphur emissions
LNG as marine fuel CO_2 carrier CO_2 transport LNG LNG fueled ship CCS	Business model Emission reduction Envisum project SECA regulation Maritime Energy Contract	Shipping Air pollution Greenhouse gases Cost-benefit analysis NOx control cost Co- benefit
Energy infrastructure Governance Polycentric LNG Baltic Sea region	Investment appraisal, VAR, Scrubber, SECA, Energy Contracting Business model	Green port Shipping Environment Emissions Climate change Congestion Intermodal Hinterland
Activity-based method Air pollution Shipping emissions Climate change	Sulphur emission control areas Maritime emissions Modal shifts Ro-Ro shipping	

Based on their abstracts, the analysed papers form 5 identifiable higher-level thematic groups: 1) Governance; 2) Alternative fuels; 3) Economic; 4) Health-Environment; and 5) Technology-Innovation. These themes are closely linked to each other, and thus the ultimate goal is to study lower emission (or even emission free) maritime transportation. Economic impacts are probably the most important issue (from a business perspective) in the discussions regarding the impacts of SECA and other emission control regulations on the maritime sector. The common outcome is that (strong) regulation is needed in order to tackle global climate change. In addition, positive improvements in air quality also have direct impacts on quality of life.

Replacing oil with alternative fuels (especially with methanol or LNG) is one way to mitigate emissions to air. Gritsenko (2018) points out that LNG, in particular, is fulfilling policy expectations in three key areas: enhancing energy security, providing low-sulphur bunker fuel, and balancing renewables in the power sector around the Baltic Sea region.

However, LNG use requires modifications in existing engines and new supply chain investments in transportation, warehousing and bunkering. The number of vessels operating on LNG is still limited but will steadily increase worldwide. Even marine transportation is producing a minor (but significant) part of harmful emissions on a global level; regional and local emissions are significant. For example, in China, there are voluntary restrictions on the use of polluting fuels like HFO due to high emission levels.

Armellini et al. (2018) note that as a consequence of the new and upcoming regulations imposed by the IMO, polluting emissions produced by large ships are now under strict control and the ECAs, which request even lower pollutant emissions, will be extended. To react to these changes, ships propelled by Internal Combustion Engines (ICEs) burning HFO can be equipped with abatement devices, such as scrubbers and Selective Catalytic Reactor (SCR) systems. However along with these solutions, other methods can be considered, such as the use of Marine Gas Oil (MGO): a more expensive fuel, but with significantly lower sulphur content. The use of MGO allows users to consider a further and more drastic modification of the power system, namely the use of Gas Turbines (GTs) in place of ICEs. Along with scrubbers, these gas turbine ships still use rather matured solutions, which are challenging to modify into zero-emission vessels.

Economic-environmental modelling is an interesting topic, which Zis and Psaraftis (2017) present in their paper. They describe a comprehensive system perspective of the maritime fuel system and an agent-based model (MarPEM) that can be used to study the effects of policy instruments on the transition away from HFO. The use of MarPEM to assess the effect of three policy instruments that each influence the maritime fuel system differently, and future studies can use this work as a basis to study the effects of other policy instruments. Similarly, Schipper et al. (2017) developed a comparative methodology to assess the sustainability performance of a mixed set of ports (different locations; sizes; profiles). This methodology involves ranking various long-term port plans and port vision documents against a set of social, economic, and environmental key performance indicators (KPIs) in order to evaluate and interpret future sustainable port-city development plans.

Reflecting on the extensive nature of the literature, it may be summarized that emission free maritime transportation is not easy to achieve with the existing matured (and polluting) technologies. A positive challenge is that there are several alternatives to lower air and sea emissions. A common feature to all these actions is that they require investments, new ways of thinking, and innovative product development of the future technologies. Currently, companies combinations of emission-lowering methods (e.g. LNG and wind assistants) that are the easiest to implement. In addition, improvements in the routing of vessels can be utilized. It is essential to recognize each individual context in the search of optimized (low or non-polluting) environmental solutions for maritime businesses.

2. DISCUSSION AND CONCLUSIONS

The identified papers indicate that the SECA regulation has been studied extensively since the discussion regarding the emission regulations in maritime sector began. Before 2015, a number of researchers anticipated considerable challenges and difficulties for the entire maritime transport sector in all SECA regions. However, the global bunker price decline mitigated the cost increase. Currently, the prices are soaring again, and the impacts will become apparent in the near future. In the Baltic Sea, maritime transport is crucial, especially for heavy export industries. Maritime transport is also the economic life-line of trade for countries such as Finland, Norway, and Sweden. The studied articles covered varying broad topics, such as the economy, the environment, modelling, governance, alternative fuels, innovation studies and health. A majority of the 21 papers were published in established and high-ranking scientific journals, even though there are only a limited number of citations since they were published recently.

In Figure 1, there is a hierarchical illustration of the SECA operators. The graph is based on the literature, indicating how the different functionalities are connected with each other. In this model, the smallest environmental 'actor' is a vessel, followed by the company (ship owner). After that, the following levels include nations, multinational collectives and alliances (e.g. EU, NAFTA), and global agreements. The lower part of Figure 1 presents key elements and options that impact emissions in this model.

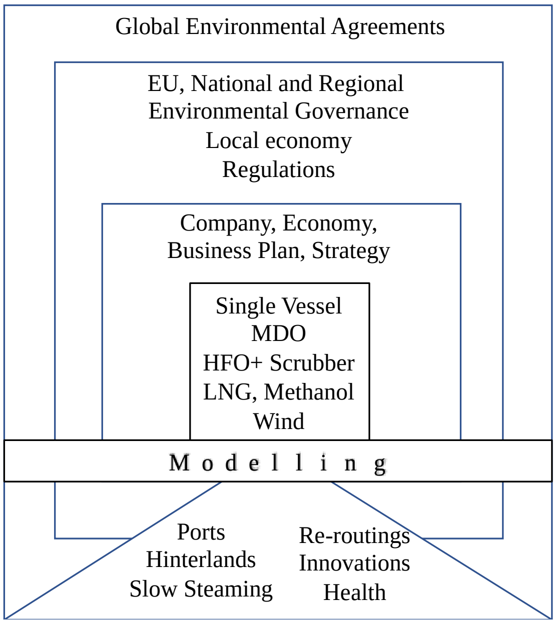

Figure 1. Operators and functions in SECA regulation according the reviewed papers.

Global environmental regulations are (and will be) created from these identified components, based on complicated and rather loose agreements. Together with the literature, Figure 1 addresses one basic reason for the extreme complexity of environmental regulation. Extensive volumes of actors, companies, and national economies are involved in this complex system. There are also various understandings regarding the goals of emission regulation. It is worth noting that the article sample did not include any papers dealing with political science or law. In the end, politics are at the centre of the whole system, as regulation decisions are always political. The articles stressed that the utilization of the environment impacts not only company balance-sheets, but also the surrounding areas and societies through which transport volumes are flowing. Therefore, regulation issues will probably become stricter and also provide new possibilities for cleaner production and environmental innovations. Particularly when new regulations are set to reduce emissions such as NOx and BC, the impacts of these constraints should be anticipated and researched thoroughly in advance.

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CONCEPT AND TECHNIQUES OF SUPPLY CHAIN FINANCE

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Abstract: *The paper addresses the relatively new concept of supply chain finance (SCF) and techniques of SCF. The flow of financial resources in supply chains is increasingly becoming the focus of attention. As a consequence, new tasks at the intersection of finance and logistics/supply chain management open new business areas for banks as well as financial and logistics service providers. Supply Chain Finance is defined as the use of financing and risk mitigation practices and techniques for optimizing the management of working capital and liquidity invested in supply chain processes. The concept of SCF covers a wide range of products, programs and solutions in the financing of commerce, including international trade, and has been used to refer to a single product, or a comprehensive range of products and programs of solutions aimed at addressing the needs of buyers and sellers.*

Keywords: *supply-chain finance, SCF techniques, finance, logistics.*

1. INTRODUCTION

Modern business conditions constantly impose change and adoption of innovations in the business orientation of all market actors. This induces the upgrading of existing business models and creates new business approaches as a way to meet the challenges and various impediments that come with a turbulent environment. Supply chain finance (SCF) is one innovation. Supply chain finance encompasses the use of financial instruments, business experience, best practice and modern technological solutions in order to achieve quick and efficient conversion of working assets in various cycles (procurement, production, sales) to cash. The result should be an accelerated operating cash flow that leads to higher enterprise liquidity.

The world economic crisis of 2008 has led to the creation of new financial instruments especially for small and medium sized enterprises. The cause of this was the inability of firms to obtain funds through traditional loaning practices. Small and medium enterprises make the vast majority of the total number of enterprises both in developed and less developed economies. The functioning of an enterprise depends on its cash flow which if inadequate can lead to illiquidity or become a constraint on enterprise growth. High

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interest rates and insufficient credit potential have led enterprises to search for new financial instruments. Supply chain finance offers such financial instruments.

The aim of this paper is to emphasize the importance of internal and external financial challenges and provide logisticians and supply chain managers with further insight for assessing the economic output of supply chain activities. The financial and operating activities of an organization are closely connected and interdependent.

2. HOW PHYSICAL AND FINANCIAL SUPPLY CHAINS ARE CONNECTED

To understand the need for and the opportunities open for SCF options it is important to understand supply chains, their management and the typical challenges faced by businesses operating within these chains. The flow of financial resources is increasingly gaining importance within supply chain (SC) analysis. New inter-functional and inter-organizational tasks between finance and logistics provide for new supply chain cost cutting opportunities.

Supply chain management has grown in importance for modern business operations. Lambert and Cooper (2000) noted that one of the most significant paradigms shifts of modern business management is that individual businesses no longer compete as solely autonomous entities, but rather as supply chains. In this emerging competitive environment, the ultimate success of the single business will depend on management's ability to integrate the company's intricate network of business relationships.

The financial and operating activities of an organization are closely connected and interdependent. Collaborating on the financial side or on the operating side, therefore brings a suboptimal result, potentially forgoing benefits that can be reaped from an approach of intertwined collaboration. Consequently, we should keep in mind that even though collaboration focuses on financial functions, institutions, and instruments of supply chains, it should not be understood as an isolated concept but rather as an aspect of a more complex system. To simplify this system, a company will choose to integrate and manage different supply chain links for different business processes. It will collaborate totally with some supply chain actors, while only collaborating financially, operatively, or not at all with others (Timme and Williams-Timme, 2000).

Financial performance of a company is dependent on its cash management and profitability. Cash management is critical for a company's survival. There are times when a company is performing well in terms of sales and services but fails to generate cash effectively. Obviously, there is a positive relationship between logistics performance and financial outcomes. Supply chain management (SCM) should always attach importance to cash flows as these bear on the financial side of business activities.

The physical supply chain (PSC) is defined as the series of business processes by which goods and services are purchased, transformed, and delivered, whereas the financial supply chain covers the series of financial processes that support the physical supply chain such as credit assessment and control, deployment of financing and risk mitigation instruments, supply chain automation processes including purchase orders, e-invoicing and payments (Bryant and Camerinelli, 2013).

In other words, the physical supply chain is a system of organizations, people, activities, information, and resources involved in moving a product or service from a seller to a

buyer, either domestically or across borders. These activities require and must be supported by financial supply chain activities.
The Financial Supply Chain (FSC) is the chain of financial processes, events and activities that provide financial support to PSC participants. Financial Supply Chain Management refers to the range of corporate management practices and transactions that facilitate the purchase of, sale and payment for goods and services. Supply chain finance is one service cluster supporting the FSC.

Effective management of the supply chain can significantly influence the level of working capital of firms. According to Porter, the two generic competitive strategies are cost advantage and differentiation (Porter, 1985). Cost advantage is achieved through reducing costs, and differentiation increases profitability by providing increased levels of customization and service. Increased levels of service can be provided through efficient order capture, product availability, on-time delivery, information transparency, and improved responsiveness.

Financial factors have a strong impact on the configuration of SC. Integration of financial aspects in the SCM allows for the systematic assessment of the impact of production decisions in the financial operation and further selects their ideal combination thus providing a competitive advantage in the company.

For chief executive officers (CEOs) focused on profitable growth, working capital control has become a key metric. Working capital represents the amount of day-by-day operating liquidity available to a business. Working capital (WC) is calculated as (EBA, 2014, 21):

$$WC = (AR) + (Inv) - (AP) + (Cash) \tag{1}$$

(AR) stands for Accounts Receivable, the amount that customers owe a business.

(Inv) is the Inventory value calculated as the total amount of inventory held by the business in raw materials, work in progress, and finished goods.

(AP) is Accounts Payable, payments due to suppliers for goods and services purchased.

(Cash) is self-explanatory.

Significant value can be derived from the optimal use of management processes in the supply chain with banks possibly supporting working capital management and the improvement of their clients' cash utilization.

Therefore, the new assignments at the intersection of finance and logistics SCM open new business areas for banks as well as financial and logistics service providers. The challenges arising with these developments bring along a new understanding and role of the supply chain actors and their relationships. New inter-functional and inter-organizational tasks at the intersection of finance and logistics open new supply chain opportunities.

3. THE BENEFITS FROM SUPPLY CHAIN FINANCE

The task of SCF is to lower capital cost by means of enhanced mutual adjustment or completely new financing concepts within the supply chain. Supply Chain Finance is an approach that focuses upon the financial problem in SC from a collaborative viewpoint.

Supply chain finance is an approach for two or more organizations in a supply chain, including external service providers, to jointly create value through means of planning, steering, and controlling the flow of financial resources on an inter-organizational level. While preserving their legal and economic independence, the collaboration partners are committed to share the relational resources, capabilities, information, and risk on a medium to long-term contractual basis (Hofmann, 2005).

The instrumental contribution of SCF is based on three constitutive elements: (1) Institutional actors; (2) SCM characteristics; (3) Financial functions. The task of SCF is to reduce capital cost by means of better mutual adjustment or completely new financing concepts within the supply chain. These elements, which can be understood as a framework of SCF, are taken into account, while making value chain decisions from a financial perspective (Timme and Williams-Timme, 2000).

3.1. The benefits of SCF for small and medium enterprises

The recent global credit crisis has prompted trade finance to look for alternatives as businesses have seen their supply chains endangered by lack of liquidity. In addition, pressure from the globalization of supply chains has increased competition and businesses are looking to SCF as one of the options for maintaining their competitive edge. Finally, as more businesses and institutions engage in various forms of SCF with deliverable benefits, this has encouraged others to participate and has further developed the market for SCF services.

Figure 1. shows the main groups of financial products which use SMEs (Van Swinderen and Mungai, 2015, 9).

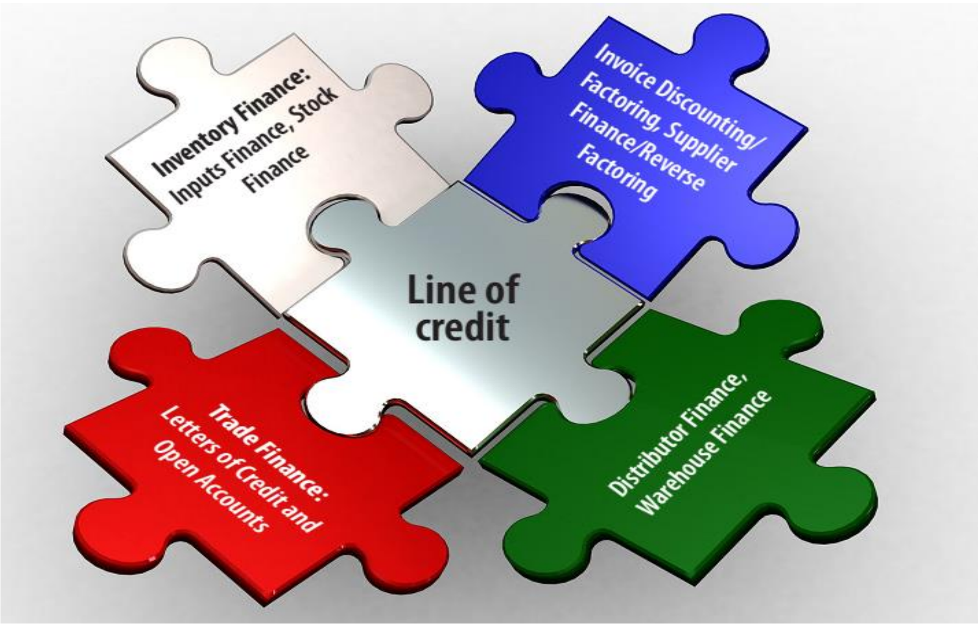

Figure 1. Key characteristics of the main product groups

Small and medium enterprises (SMEs) credit risk is typically more challenging to assess than that of larger businesses. Many have struggled to gain access to traditional forms of finance. Practical SCF approaches create an opportunity to significantly improve access to finance or reduce the need for external financing by unlocking potential liquidity from within supply chains. There are both quantitative benefits as well as qualitative benefits from SCF solutions.

The main benefit of supply chain finance is that the buyer does not pay any fee to extend its payment terms and the supplier only pays a small discount if he wants to get paid early. Supplier finance works for companies in a variety of sectors, including automotive, electronics, manufacturing, retail, and many others. It works for companies on both sides of the supply chain. Buying organizations can extend their payment terms, and suppliers can get paid earlier. Supply chain finance is a true positive sum game solution for both trading partners.

Though supply chain finance and logistics, it is possible to achieve a win-win situation between core enterprises and their SMEs partners. SCF enables banks to support SMEs at a level that is more in line with their trading activity. By contrast, traditional forms of bank finance are primarily dependent on the SME's balance sheet strength, security values and the value of supporting guarantees. Finance availability is constrained by factors that are unconnected with an SME's trading activity.

4. TOWARDS STANDARD MARKET DEFINITIONS FOR SCF AND SCF TECHNIQUES

The market for SCF is still evolving and the next levels of definition for SCF structures and components are not well established. Banking associations and other organizations have already started to acquire knowledge to support their membership and associates in adopting common definitions and terms.

There is a need for much greater clarity of definitions, conceptual language and commonly used terms. This is illustrated by the definition of Supply Chain Finance itself, which sometimes is an umbrella term for a whole range of financial instruments and sometimes denotes a specific technique or component of the SCF portfolio. SCF is most commonly described as a portfolio or series of financial practices and technologies that support the trade flows and financial processes of end to end business supply chains. This is a holistic definition including a broad range of traditional and evolving financial techniques. Supply Chain Finance is defined as the use of financial instruments, practices and technologies to optimize the management of working capital and liquidity tied up in supply chain processes for collaborating business partners (EBA, 2014).

The Global Supply Chain Finance Forum was established in January 2014, as an initiative of a number of sponsoring industry associations facilitated by the International Chamber of Commerce Banking Commission, to address what has been recognized as a need to develop, publish and propose a set of commonly agreed standard market definitions for SCF and for SCF-related techniques. Through this document the sponsoring associations of the Forum have confirmed their support for these standard market definitions which are now recommended to the wider stakeholder community for adoption (BAFT et al. 2016).

The purpose of this initiative is to help create a consistent and common understanding about Supply Chain Finance starting from the definition of terminology, to be followed by advocacy in support of the global adoption of the standard definitions. It is recognized that SCF propositions have evolved at different ways and in varying directions by region and at the level of individual providers. However, the view is that there is agreement on the clear benefits to the financial industry, regulatory authorities, clients and other stakeholders, from the development and dissemination of standard definitions and terminology.

SCF products and services cover all risk mitigating and liquidity products a corporate client requires to optimize working capital along the entire value chain. It comprises both traditional and other products and services such as Open Account techniques generally designated as SCF.

The value of a standard global terminology around SCF extends beyond pure financial transaction side rations, to the areas of automation, dematerialization and technology. Supply chain automation based on dematerialization, from e-procurement, to e-invoices and to e-logistics, coupled with data-driven decision-making, enhances efficiency and creates efficient financing instruments which can be provided across international and domestic supply chains.

It has been decided to create a Global SCF Forum to develop a set of standard market definitions for the range of SCF instruments offered by the market. It is expected that all stakeholders, e.g. customers, banks and nonbank finance providers, regulators and investors will benefit from the clarity that these definitions will deliver.

Figure 2 presents that SCF techniques (Bryant and Camerinelli, 2013, 29).

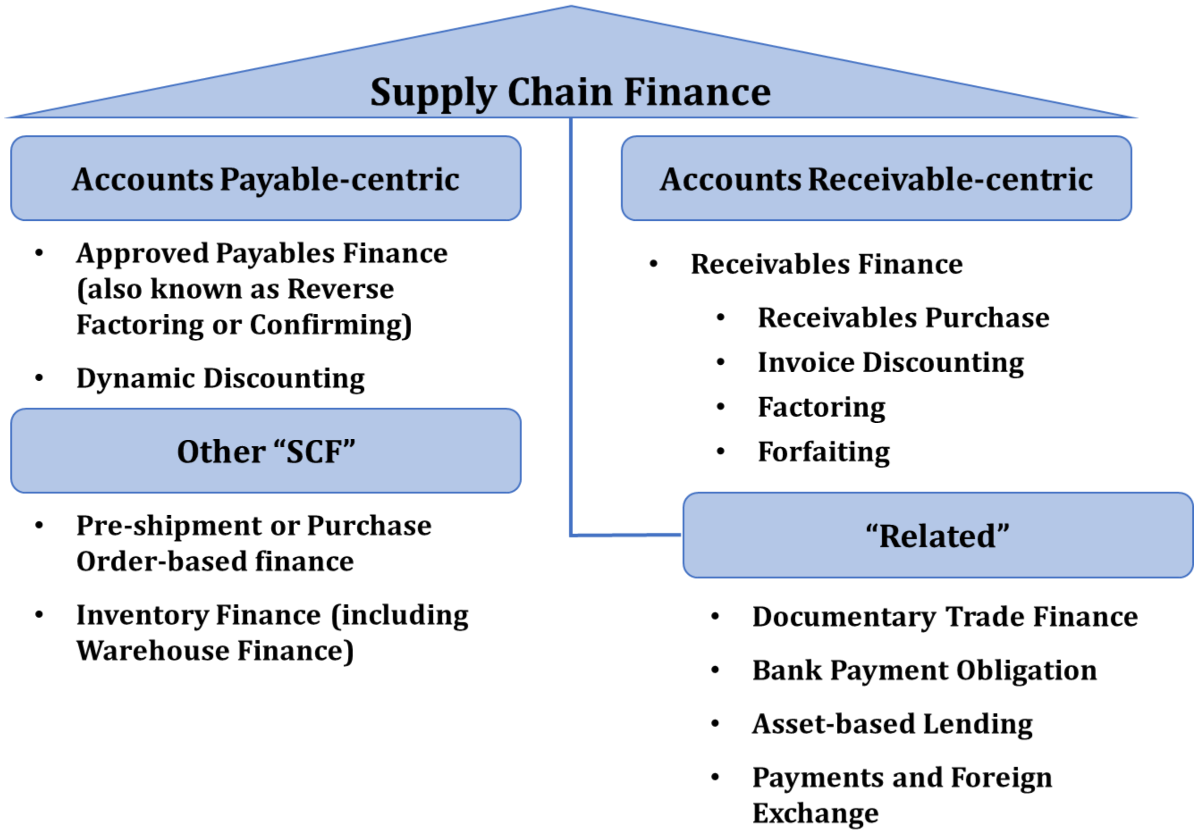

Figure 2. Supply Chain Finance Portfolio

Distribution of SCF instruments is given in Figure 3 (EBA, 2014, 29). The receivables financing segment including factoring, invoice discounting and receivables finance in all its forms remains the largest segment with an estimated 60-70% market share. Buyer-centric SCF techniques, such as Reverse Factoring or Approved Payables Finance, represent less than 15-20% of the market but have strong growth potential. Global banks are today mainly concentrated on the large buyer side of the trade equation. This is the heritage of the cleverly structured solutions engineered and provided by banks for large international trading companies. In particular the value of this SCF technique in stabilizing the SC, directing liquidity to where it is needed, and creating a win-win situation for buyers and their suppliers is increasingly recognized.

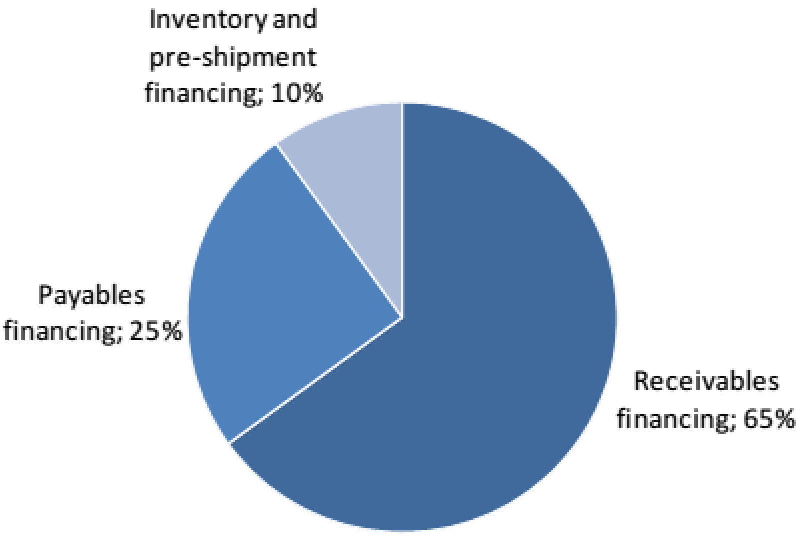

Figure 3. Distribution of SCF Instruments

A large number of drivers are encouraging the growth of SCF. Let us mention a few.

1. As credit spreads have widened there is more scope to develop new approaches to pricing these alternative structures. On both the supplier and buyer side, the availability of working capital throughout the supply chain is a key issue.
2. Buyer-centric SCF supports the objective of de-risking the supply chain and relieves suppliers. Many of them are SMEs. Leveraging the credit strength of highly rated buyers seems a sensible and an unused opportunity.
3. Many of the institutional ingredients are in place. These are well-connected supply chains, financial institutions and other essentials such as B2B automation platforms and networks. The latter can enable the evolution to a widespread SME support based on automation, especially e-invoicing.

5. CONCLUSION

Many executives are beginning to understand the intrinsic connection between competency in physical supply chain management and corporate performance measured in financial terms. For that reason, supply chain professionals must be ready to deliver value through their own local initiatives in order to support their companies' strategic visions and overall performance.

Further work is needed to harmonize SCF existing market terminology to make it operational and usable in daily practice by banks and non-banks when processing, financing and risk mitigating trade transactions.

ACKNOWLEDGMENT

This paper was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia through project number TR 36006.

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FREIGHT FORWARDING INDUSTRY - THE CONTEMPORARY ROLE AND DEVELOPMENT TRENDS IN SERBIA

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Abstract: *The freight forwarding industry has been changed and developed through the history, as a result of the development in trade, transportation, other related industry sectors, logistics and information technologies, laws, and other social, economic and political changes. By using the available literature and analysing the statistical data of EU and Serbia, we examined briefly the current role and development trends in the freight forwarding industry, following the NACE industrial classification of economic activities. The results confirmed that this subsector has a crucial importance within the logistics sector and, consequently, in the national economy on a whole. In the same time, it is highly diversified on the market, "hidden" and underestimated in the classification of activities, and not precisely recognized by current NACE classification. Further, the freight forwarding industry in Serbia shows some specificities comparing to the EU experience.*

Keywords*: Freight forwarding industry, Development trends, Sectors classification, EU, Serbia.*

1. INTRODUCTION

The freight forwarding (FF) industry has been changed and evolved during the centuries. Many factors have contributed to these changes. In the recent period, the most influential factors are trade development, globalization, and rapid changes in transport and logistics technologies, information technologies and legislative which regulate different stages of international trade [1]. These impacts are so high, that some authors hypothesized the extinction of traditional freight forwarders in the forthcoming period [2]. Additionally, other social, economic and political changes may also strongly impact the development of the freight forwarding market. For example, in some former socialist countries, privatization, economic transition, and entrance to the open and global markets put additional significant challenges in the business operations for freight forwarders [3].

The purpose of this paper is to explore the evolution and the current role of FF within the logistics sector in the case of the Republic of Serbia and compare it, as much as possible, to the EU experience. For the theoretical considerations, we reviewed briefly the academic

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literature and the viewpoints of The International Federation of Freight Forwarders Association (FIATA). Some of the main characteristics of the FF industry evolution, practice and experience are more or less applicable worldwide. For the empirical part of the research, we used the available statistical database about the firms in the logistics industry in order to compare the role and significance of FF to other activities within the logistics sector. The current classification of logistics companies according to NACE and national classifications and the position of the FF companies is also reviewed.

The paper structure is as follows. In the second section, the evolution of companies in the market of the FF industry is briefly presented. The methodology for empirical analysis of the role of the FF industry within the logistics sector in EU and Serbia is described in the third section. Here is also stressed the position of freight forwarding industry from the perspective of the current NACE classification of activities. The main empirical results are presented in the fourth section, whereas discussion and concluding remarks are presented in the fifth section. The conclusion is given in the last section.

2. THE ROLE OF FREIGHT FORWARDING INDUSTRY

The development of the FF industry and the changing role of a freight forwarder are strongly related to many complex impact factors, such as globalization, a rapid increase of international trade and technology development, including information technology. Due to the development of IT-based supply chain integration, value-added service offerings and increased requirements for cargo security, the traditional freight forwarder is being forced to evolve, or else risk extinction [2].

Traditionally, freight forwarding is an economic activity responsible to manage moving goods, typically in international trade. Freight forwarders are responsible for planning and organization of moving goods, networking of all parties involved in delivery and coordination between them, controlling all processes and actors from the departure to the point of delivery. They care about all administration and documents handling. They may have warehouses or transport fleet, but transport and storage are considered as additional, support activities to the main task. However, due to the increasing complexity of activities which perform different intermediaries and evolving the most developed freight forwarding companies into logistics integrators, the definitions of freight forwarders has started to be changed in scholar books, by the most relevant international FF associations, in the national and international legislation and regulative instruments.

The contemporary approach assumes that freight forwarding comprises all activities related to managing *and performing* logistics activities and other supporting activities to transform the goods through the time and space, reaching the 7R's logistics objectives (the right goods, at right quantity and in the right conditions, at the right time and right place, with the right price, to the right customer) [4]. The evidence may be found in changing terminology by the national and international freight forwarding associations. Also, the changes have been recorded in their terms and regulations related to the basic freight forwarders roles. The last definitions of the most important freight forwarding organization FIATA (The International Federation of Freight Forwarders Association) completely reveal the complexity of the industry:

"Freight Forwarding and Logistic Services" means services of any kind relating to the carriage (performed by single mode or multimodal transport means), consolidation, storage, handling, packing or distribution of the Goods as well as ancillary and advisory services in connection therewith, including but not limited to customs and fiscal matters, declaring the Goods for official purposes, procuring insurance of the Goods and collecting or procuring payment or documents relating to the Goods. Freight Forwarding Services also include logistical services with modern information and communication technology in connection with the carriage, handling or storage of the Goods, and de facto total supply chain management. These services can be tailored to meet the flexible application of the services provided.

(FIATA, 2004) [5]

Freight Forwarding Services means services of any kind relating to the carriage, consolidation, storage, handling, packing or distribution of the Goods as well as ancillary and advisory services in connection therewith, including but not limited to customs and fiscal matters, declaring the Goods for official purposes, procuring insurance of the Goods and collecting or procuring payment or documents relating to the Goods.

(FIATA, 2007) [6]

These definitions do not offer a clear boundary between the logistics and freight forwarding services; they rather point out their interdependence and overlapping in industry practice. Freight forwarders may be all kind of intermediaries in moving goods, but also parties which perform the delivery and offer the whole package of services. Thus, the research question is: how to differentiate freight forwarders from other logistics providers and what is their role in the logistics industry?

Today, successful freight forwarders may be enterprises of all sizes, from the micro-sized ones highly specialized for a particular market niche to global logistics companies who offer "door-to-door" delivery. They operate as a wide range of intermediaries, with different roles in different legal systems (principals, a wide range of agents, carriers, customs brokers, multimodal transport operators). The diversity of their activities is high, from customs brokerage, over arranging all transport operations by rail, road, sea or air, including multimodal transport, to performing all logistics operations to provide "door-to-door" delivery. Some of the traditional freight forwarders from the end of XIX century have been evolved into the regional and global 3PL and 4PL providers and integrators, and the most powerful companies in the logistics industry in the XXI century [1, 7]. As some authors noticed, "logistics intermediaries come in different forms and under different names, but they all have the same goal: to provide help to companies in the transportation, storage, shipment and the distribution of goods from the seller to the buyer or the final consumer..." [8]. There is no doubt that their role is crucial in international trade flows. FF companies support approximately 95% of international trade flows in Serbia [3].

The freight forwarding market is still fragmented everywhere, with a mix of global providers and many small competitors [9]. Authors Kilibarda et al. [3] figured out three types of freight forwarding companies in Serbian market: two out of them are basically intermediaries (customs brokers, or brokers in transport and organization of trade flows) and the last group comprises the companies that provide a wide range of logistics services (packing of goods, consolidation, transportation, storage and reloading of goods, preparation of documents, customs clearance, transportation insurance). On the market, they are both competitors and partners. In many cases, multinational providers outsource part of services to medium or small-sized freight forwarders, custom clearance agents and logistics providers to expand their business. The evolution of freight forwarding companies, as well as the typical players in the modern market, is shown in Figure 1. The positions of the various players in Figure 1 merely, although not inevitably indicate their relative size.

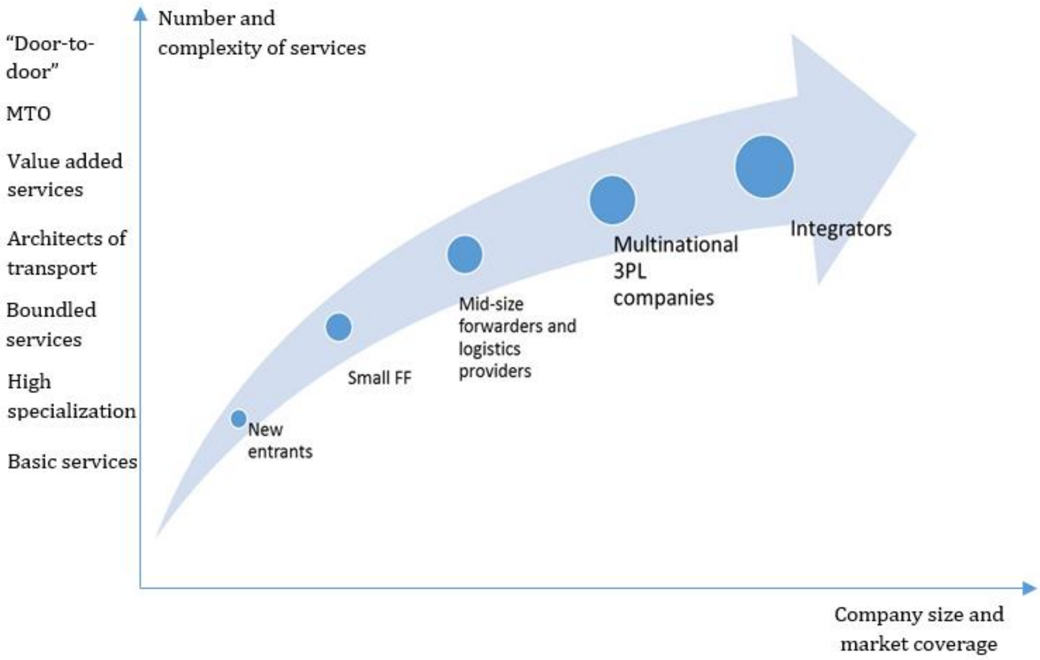

Figure 1. The evolution of freight forwarders (adapted from [2, 4])

All freight forwarders on the market have to cope with many challenges. The challenges or their priorities partly depend on the type of FF company. However, some challenges are common for all players: the competition and risks are higher than ever before, customers' relationships are evolving and more demanding than ever, there is more dependence on the integration of processes, and the value of information is increasing [2]. Small enterprises additionally have to cope with the power of bigger players around them, whether they are competitors, customers or other contractors in the same supply chain. Moving into the next-level category may be through company size expanding (e.g. acquisition and merging), but also through networking and collaboration. However, small freight logistics providers can be successful in their market niche if they provide competitive service. The new entrants in the market are usually new customs brokers and smaller freight forwarders.

3. METHODOLOGY - A CASE OF SERBIA

We used the data obtained from the Serbian Business Registers Agency (SBRA) and available by the Eurostat to perform empirical analysis and answer on the research question. All codes which cover moving, handling and storage goods as the primary industry according to the Statistical classification of economic activities in the European Community (NACE) are included in the analysis. It has to be pointed out that the data are different from those shown in the Statistical Yearbook, due to different methodology. The Official Yearbook does not have data which cover particular activities in the logistics sector, as given in Table 1.

Currently, according to the NACE, the logistics sector comprises activities with codes from 49 to 53 (Table 1). Passenger transportation is excluded from the analysis. Pipeline transport is also excluded due to its high specificities, although it belongs to the logistics activities.

Table 1. The list of activities which belong to the logistics industry (according to NACE Rev. 2 H-N and S95)

Codes and classes		Codes and classes	
49	- Land transport and transport via pipelines	52	- Warehousing and support activities for transportation
49.2	- Freight rail transport	52.1	- Warehousing and storage
49.4	- Freight transport by road and removal services	52.10	- Warehousing and storage
49.5	- Transport via pipeline	52.2	- Support activities for transportation
50	- Water transport	52.21	- Supporting activities in land transport
50.2	- Sea and coastal freight water transport	52.22	- Supporting activities in water transport
50.20	- Sea and coastal freight water transport	52.23	- Supporting activities in air transport
50.4	- Inland freight water transport	52.24	- Handling
50.40	- Inland freight water transport	52.29	- Freight forwarding
51	- Air transport	53.	- Postal and courier activities
51.2	- Freight air transport and space transport	53.20	- Other postal and courier activities
51.21	- Freight air transport		
51.22	- Space transport		

It could be expected that the group 52.2 – " Support activities for transportation" does not include logistics activities, but rather infrastructural and similar activities (e.g. roadside assistance, railway stations, etc.) [10]. However, the group 52.29 – "Other transportation support activities" mostly contains freight forwarding companies and logistics providers both in Serbia and the EU. Actually, supporting activities, except freight forwarding (52.29) and handling (52.24) are related to both, passenger and freight transport and cannot be clearly assigned to the logistics sector. Consequently, all indicators related to this subsector has the methodology limitations.

4. RESULTS

The role of FF in the logistics industry in EU 28 and Serbia in 2016 is presented by three indicators in Table 2 – the number of enterprises, overall turnover and the workforce volume, as well as its share in the total logistics industry. In the EU, freight forwarding was the second largest sector in the number of employees and the number of enterprises in 2011, with the share of 17,4% in the total number of enterprises and almost one-third of employed persons in the logistics industry. The class "road freight transport" had the highest share in the number of logistics enterprises (75%) and the highest share of the employed workforce (45%) operating in the EU market [10].

Table 2. The main indicators of logistics industry in EU and Serbia in 2016 (Data sources: [11, 12])

Class	No. of enterprises		Overall turnover in %		No. of employees	
	EU	RS	EU	RS	EU	RS
49.20	692	13	1,85%	3,62%	135.126	4.004
49.41	575.000	3.125	31,34%	45,85%	3.154.630	19.988
50.20	5.203	5	7,81%	0,18%	80.455	22
50.40	5.736	40	0,46%	2,22%	83.773	916
51.21	735	-	/	/	22.316	-
52.10	22.505	129	8,35%	13,35%	599.707	1.279
52.21	38.058	238	7.47%	7,15%	517.744	13.530
52.22	9.564	20	2,18%	0,16%	:	95
52.23	5.132	25	5,11%	5,79%	301.013	3.137
52.24	11.291	43	2,67%	1,00%	250.917	709
52.29	**71.978**	**1.226**	**25,41%**	**18,29%**	**1.112.722**	**8.573**
53.20	77.665	43	7,36%	2,38%	867.419	2.265
Total	**826.860**	**4.907**	**100,00%**	**100,00%**	**8.091.410**	**54.518**

The crucial importance of FF group of activities in the EU was also recorded in 2016. It kept the position of the second important class of activities in turnover (share of 24,27%) and employed persons (share of 13,75%) in the logistics industry. It should be noted that compared to the recorded number of enterprises and the employed workforce of the class 49.41 - Freight transport by road, the turnover in the FF industry was achieved by much fewer resources.

However, compared to the reached turnover of EU countries in 2011 in the same class of activities [10], there is a significant decrease. Among the main reasons for such big discrepancy, the changes in the logistics market seem to be more influential than the EU enlargement for one country. For example, the EU logistics sector recorded a significant increase of the market of couriers, express and postal industry (the class 53.20). This is important from the perspective of FF industry because this class also comprises logistics integrators, such as DHL, TNT, FedEx etc. They offer globally “door to door” service, and usually own significant logistics resources and infrastructure to provide high-quality service worldwide. The importance of these players in the European logistics sector certainly increase. Though, this class of activities also covers the courier service and the increased importance of this industry cannot be simply related only to the increased importance of integrators. The reasons for changes are probably not exhausted and it could be interesting to explore them more in-depth in the future.

In Serbia, FF is also the second important class of activity (after road freight transport), with 24,98% share of FF firms in the total number of logistics firms, and the third important in the total logistics industry workforce with 15,73% share of employees [11]. The share of turnover (18,29%) is also on the second place, after the road freight transport. It is lower comparing to EU experience, whereas the bigger share of smaller enterprises is also recorded (persons per enterprise employed, Table 3). On a whole, the numbers indicate a dominance of small freight forwarders in Serbia, with less turnover and workforce than the ones in EU, which may imply a less power compared to the freight forwarding enterprises in the EU. Regarding the workforce skills, a survey conducted by EU in 2011 [10] revealed that 40% of freight forwarders consider a shortage of skilled staff in the FF industry as a question of “high or very high relevance”. The comparative research for Serbia was not performed, but the one of rare research on FF service quality in Serbia, conducted in 2011 by Kilibarda et al. [3], revealed that the logistics service quality of freight forwarding companies in Serbia is not at a satisfactory level. Although the underlying reasons are not explored, it could be supposed that the workforce skills may be among the main ones.

Table 3. The comparative overview of the role and significance of freight forwarding sector (class 52.29) in Serbia and EU – the share in the logistics sector in 2016

	Share of enterprises	Share of turnover	Share of employees	Number of employees per enterprise
Serbia	25%	18%	12%	7
EU 2016	9%	24%	14%	15

Warehousing is usually another big contributor to the added value of outsourced logistics activities in the EU, after land transport [10]. In Serbia, this is the third important activity in turnover and number of enterprises, and the second one in the workforce. One may notice that both road freight transport and warehousing services are usually among the basic logistics services of freight forwarders and there is a possibility that some of the important freight forwarders are also “hidden” within these classes, in cases where the freight forwarding services are classified as the ancillary activities.

The European experience also confirmed that some of the most important players in the logistics sector like Schenker, Gefco, Hoyer, Hermes Logistics, DHL Freight, and some other companies, which are among the biggest logistics service providers in Europe, are classified mostly as the Class 52.29 [10]. In Serbia, the 10 best freight forwarders were Milšped, Kühne + Nagel, MSC, ASV, PRO TEAM, Transportšped, Transprom, Cargo Agent, Eurologsystem and Same & Same, are listed regarding their profit in 2016 (source: SBRA, 2018). Among these firms, small enterprises prevail, whereas most of them realize a range of additional activities rather than belonging to the traditional freight forwarders. Also, it should be noted that the size of an enterprise does not reflect necessarily the real role of SMEs on the market. For example, many global companies have local subsidiaries registered in Serbia like SMEs (i.e. the Kühne + Nagel doo Beograd), although in reality, they are part of the global logistics providers. This is an additional limitation to the assessment of the real role of SMEs in the FF industry.

5. DISCUSSION

Two main conclusions raised from the results. Firstly, the sector classification and statistical data do not reflect the real role and the real state of freight forwarding. Some other authors also indicate this discrepancy between the FF role in the logistics industry and its current position in classification (e.g. [13]). The presented results underpin such a viewpoint. Secondly, current classification does not fit to the FF practice. Small freight forwarders may provide also basic transport and warehousing services, medium-sized may be also exporters or importers, whereas the biggest players are integrators which may be classified into express and courier companies. The companies which perform other activities than logistics may also act as successful freight forwarders on the market. Other logistics, or even trade and manufacturing companies may have developed freight forwarding activities as the very significant source of the turnover, but still be recognized as the ancillary activity. The freight forwarding activities in such enterprises are invisible within the current statistical methodology. For the purpose of statistics, companies will be classified according to the most profitable activities.

As a result, we have a blurred picture of the enterprises in the FF market, and a lack of accurate statistical data. There are many limitations which indicate that statistical numbers have to be used carefully in analyses and policymaking. The main reasons for an unclear picture about the role and importance of freight forwarding activities may be as follows:

- The evolution of the freight forwarding industry, especially in several last decades,
- The official statistical methodology limitations,
- Changing laws and regulations on the freight forwarding industry, which are not followed by changes in sectors classifications.

All three reasons may contribute to the dispersion of FF enterprises throughout several classes. Additionally, the serious weakness of NACE classification is that such an important group of activities is not clearly recognized. Freight forwarding should be recognized clearly in classification and methodology description, as a separate class. It is too much important to be classified as the “other activities” and coupled with enterprises which are not in freight forwarding sector. Currently, there is still a possibility that firms with other activities than FF could be classified in this group and thus cause additional bias in different analysis.

In the future, it is expected that the freight forwarding market will remain to be a mixture of companies with different size, diversified services and competitive resources, as well as with a number of market niches. The enterprises will be both competitors and “complementors” (firms contracted by the main FF company to perform complementary/supporting services) on the FF market in their efforts to design, coordinate and perform complex supply chains and networks. The niche markets will be determined by the FF companies’ size, the group of activity, industry and geographic focus in international trade, etc.

Presented research has some limitations. The analysis is not quite consistent with the EU ones. The EU also includes pipeline transport. Still, it is not expected that enterprises in this class have a significant role in the Republic of Serbia compared with total logistics sector. The class “53.10 - Postal activities under universal service obligation” was also excluded from logistics sector, although there could be noticed the efforts of universal postal operators to find a new, more competitive role in the courier and express market.

6. CONCLUSION

It could be concluded that the freight forwarding subsector is very significant and, at the same time, surprisingly underestimated in the official statistical industrial classifications, or not exactly covered by this classification. Recent research showed that in the EU and Serbia, this is the second important logistics class of activities in the turnover and the number of enterprises (after the road freight transport). Also, in both cases the share in the logistics workforce is among the top three classes.

All results suggest a necessity to consider the classification improvement for the freight forwarding, careful usage of the statistical data by the policymakers, and more careful approaches in research related to the freight forwarding industry. Some of the companies, which belong to the most evolved freight forwarders ("integrators"), are usually classified into the class "Other postal and courier activities", which has recorded increase in the recent period. Other methodology limitations also contribute to the misperception of the FF role in logistics industry and, consequently, for the national economy on a whole.

Finally, following high diversity of the market, limitations of official NACE classifications and wide definitions of the most prominent international associations, one may ask how to differentiate freight forwarder from all other logistics providers in the logistics industry. The answer may be as follows: if the logistics provider act as any kind of logistics intermediary in supply chains, he or she may be classified as the freight forwarder (in a wider sense), recognized on the market and may join related national or international associations, if interested. If freight forwarding activities prevail among a variety of activities, such kind of company will be also recognized in official NACE classification. But if logistics providers offer only basic transport, storage, package or other logistics activities which need assets (warehouses, fleet, plants, equipment etc.) they cannot be mixed with freight forwarders anyway. Bringing the main value may be facilitated by the owned infrastructure and assets, but not based on basic services. The added value is also the main distinctive characteristics between different kinds/evolution levels of freight forwarders in the market.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia [project No. TR36030].

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HUMAN RESOURCES IN LOGISTICS AND SUPPLY CHAINS: CURRENT STATE AND TRENDS

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Abstract: *This paper presents the results of the research of human resources in logistics and supply chains. The analysis covered different researches in developed and developing countries. The needs and problems with labor shortage, required logistics competencies and skills, as well as problems and solutions related to employment and retention of the labor are considered in detail. The results of the research conducted by authors in the Serbian market are presented. Also results showed that there is a large fluctuation caused by salaries, inability to progress and lack of vision of the company. The research was carried out on a sample of 314 respondents of mainly highly trained logistics specialists in different positions and in different industries. The results of all researches have shown that there is an evident lack of logistics experts in all positions and in all countries and regions. The situation is similar in the Serbian market.*

Keywords*: human resources, logistics, supply chains, recruitment, retention*

1. INTRODUCTION

Logistics is a key factor in economic development, economic growth, spatial integration and market integration. It has a significant impact on economic performance in different industries and national economies. Unlike the past, today the importance of logistics and the need for its construction and development on a global, regional and local level is becoming more and more important. When discussing the development of logistics, it is mainly thought of logistics and transport infrastructure, harmonization of regulations and law, ie creating an economic environment and facilitating the undisturbed flow of goods, people and capital. However, the growing problem is the workforce, logistics competencies and skills. It is labor intensive activity and despite the high level of technological development, process mechanization, automation and robotization, the main resources are personnel and labor.

The construction and development of human resources is equally, if not more important than the construction of infrastructure. Researches carried out in recent years in many developing and developed countries has shown that companies have significant

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difficulties in hiring staff with the necessary skills and knowledge to manage logistics processes and supply chains. The results of the researches show that logistics staff at all levels from drivers, warehouse workers to the senior managers in the supply chain are missing. A similar situation exists in Serbia where problem of finding workers with certain qualifications and skills is oftenly recognized.

Generally, in the professional public, there is general consensus on the importance of human resources in logistics and supply chains (Cottrill & Rice Jr. 2012; Ellinger & Ellinger 2014; Fisher et al. 2010). In spite of this fact, this topic is not being explored and processed enough. For example, in scientific journals in the field of logistics and supply chains only 0,57 papers deal with this issue. Of this, 87% of the articles are related to the issue of logistics competencies (Hohenstein et al. 2014).

The above facts and general state of logistics staff were the main motives for researching and writing this paper. The main goal of the paper is to research and review the existing situation, and provide specific suggestions and guidelines for the development of human resources in logistics and supply chains. The results of the conducted research are presented through two parts. In the first part, a summary of the situation in the world is given with special emphasize on needs and shortage of the workforce and competencies as well as recruitment. The second part of the paper is related to the results of the research in Serbia. In the last section concluding remarks and future research directions are given.

2. CURRENT STATE AND TRENDS OF THE LOGISTICS SECTOR IN THE WORLD

An analysis of the current situation and trends in the world has been carried out on the basis of a large number of research results and papers published in recent years. One of the most important and most complete research was realized by the World Bank and its research partners from the Kühne Logistics University in Hamburg, Germany. This research deals with logistics skills and competencies at the global level. The researchers dealt with challenges in recruitment and retention of the workforce in both developing and developed countries. Some of the most important results that researchers have come up with are presented in the following parts of the paper.

2.1 Needs and shortage of the workforce

In the last years, the need for qualified labor in logistics has grown considerably. This is the result of the growth of economic activities, the spatial dispersion of production and consumption, the expansion of companies on the international and global level, the increasingly complex and stringent demands in logistics and supply chains. It is estimated that labor demand in logistics in the world is growing at a rate of 10-12% per year. The results of research in different parts of the world show the shortages of the workforce with appropriate logistics competencies and skills. Shortage range from the lack of drivers to the problem of filling higher supply chain management positions. It is estimated that this problem will remain the same in the next five years. In developed countries, shortcomings relate to all levels of logistics profession, but are more present at lower levels. Developing countries are seriously confronted with a weak supply of skilled labor, although there is a high level of unemployment in these countries. The lack of staff with the skills necessary for the supervisor and higher logistics management positions is especially emphasized in these countries. The lack of specialized schools and faculties that would train professional labor has been noticed in developing countries. Researches indicate a significant gap between the significance and availability of the logistics staff with the appropriate skills needed to perform tasks on certain positions in the supply chain (figure 1).

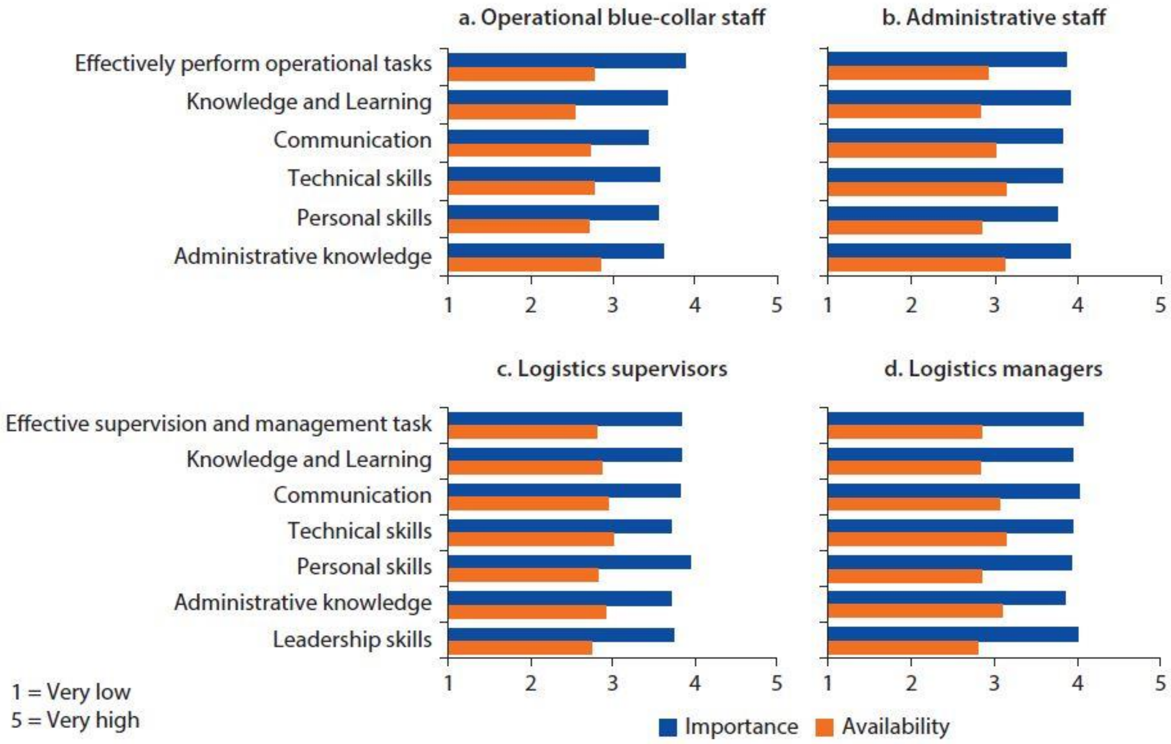

Figure 1. Gap between importance and availability of competences (McKinnon et al. 2017)

The significance of all logistics skills is a very highly graded (average grade 4 on scale 1-5), while the availability of staff with these skills is considerably worse (usually 2,8-2,9) (McKinnon et al. 2017).

It is considered that poor availability of staff with the necessary logistics skills is small for two key reasons. The first reason is that there are not enough staff on the labor market with appropriate skills and qualifications. Another reason is the lack of skills in the existing logistics workforce. Rapid technological development in logistics and supply chains requires new competencies that the existing labor does not possess. A large number of employees in logistics can not follow technological innovations, great dynamics in the market, complex operating and work procedures.

There is an expert consensus on the reasons for the lack of staff with the necessary logistics competencies and skills. The potential for employment in the logistics sector is oftenly limited by its relatively poor image. In most countries, the logistics sector suffers from low economic and social reputation and status in relation to other professions (McKinnon et al. 2017). This directly affects career planning where talents and potential managers choose other professions and give up on logistics. The salaries of employees in logistics are significantly lower in relation to some other professions, which places this sector in an inferior position when choosing a profession and employment. This particularly applies to workers on operational level. One of the reasons is definitely characteristics of the operational tasks in logistics. In many positions, these are very stressful and dynamic jobs with hard work and night shifts. Also, many logistics companies are located far from towns and places of residence in industrial areas or locations that are close to the highway, which directly affect travel time to and from work (Sheffi 2013).

2.2 Competencies of the logistics workforce

Different researchers found what skills are crucial for managers in supply chain management. According to Harvey and Richey (2001) managers should have managerial and transformation-based skills. Richey et al. (2006) found that verbal IQ, achievement-orientation and high adaptability are crucial for managers. Beside managers, all logistics employees must have skills associated with understanding various business fields, strategic decision-making, communication, leadership and IT in order to cope with daily tasks (Hoberg et al. 2014). Based on the results of the research, which was conducted in Poland based on the sample of 500 people it was found, that more than 50% of the respondents think that activities performed by logistics employees are crucial for enterprise. Only 6% thought they do not have crucial role. When asked about crucial employee's characteristics, respondents marked responsibility (21,4%), creativity (19,5%) and ability for team work (17,4%) (Slusarczyk and Kot, 2011). Results of the research also showed crucial science domains, which are most frequently used at work and which should be the foundation of education. Those domains are associated with marketing, IT, HR management and foreign languages (Slusarczyk and Kot, 2011). Research conducted by Thai (2012), also had the goal to determine what skills logistics labor should have. Author found that the most important skills and knowledge are personal integrity, managing client relationships, problem-solving ability, cost control and ability to plan. The least important skills and knowledge according to this research are packaging, managing returned products and scrap disposal, international business regulations and knowing two or more languages. Poorly positioned and assessed knowing two or more languages is due to the fact that respondents were from Australia, where English is the native language. When asked about the most important skills, senior level respondents rated analyzing statistical data, marketing, HR management, strategic management, understanding economic principles, engineering logistics and ability to organize as the most important ones Thai (2012).

2.3 Recruitment and retention

Key challenges which are HR facing in today's market are recruitment and retention of the labor. Firstly, companies cope with problem of recruiting employees where labor shortage exists. Beside salary, benefits and security, as the most important factor for recruitment was found to be transparent career path to senior management (McKinnon et al. 2017). One solution which can help with recruitment of the labor is investing in employer branding, which can be a decisive factor in choosing a company. This method is more effective when choosing top management, but gap still exists on entry-level. In order to solve this problem there are some solutions which can be adopted. Namely, companies can connect with student before their graduation, help them with their projects or even give scholarships, after which students would have to work for the company for a certain period. In today's market, where fluctuation is greater than ever, companies face problems associated with retention of labor. Problem of retention is maybe even bigger than recruitment, mainly because people are willing to change company for a better working conditions. Competition exists even between sectors (in the same company), not just between companies. As a consequence of this, logistics sector cannot compete with other sectors like sales, marketing or finance. For that reason, logistics sector must provide and emphasize other factors which are crucial for retention, other than salary. These factors are: number of working hours, working environment, job satisfaction, etc. (McKinnon et al. 2017). Beside recruitment and retention, according to World Bank study, keeping salaries and benefits competitive and succession planning are the two most challenging tasks for HR in logistics (when observing emerging regions). When observing developed regions, two most challenging tasks are developing leadership skills and keeping salaries and benefits competitive (McKinnon et al. 2017).

Table 1. Factors for retention by sector (Source: McKinnon et al. 2017)

Factor for retention	Supply chain (%)	Logistics sector (%)
Terms and conditions (pay and working hours)	45	34
Working environment	20	18
Limited opportunities elsewhere	19	17
Job satisfaction	18	23
How staff are treated	15	17
Job security	14	14
Company reputation	13	11
Training opportunities	9	6
Family-run business	5	7
Staff loyalty	5	9
Others	16	42

3. CURRENT STATE IN SERBIA

Research on the state of human resources in the field of logistics and supply chains in the Serbian market was conducted according to the developed methodological procedure based on the survey research. A questionnaire had 20 basic questions, after which a target group of respendents was defined, comprised of logistics experts at various positions in the supply chain. The questionnaire consists of two parts. The first part is related to the characteristics of the sample, while the second part is related to the state and characteristics of human resources in logistics and supply chains. The questionnaire was first tested on a sample of 30 respondents and when its validity and credibility was confirmed, it was sent to the respondents via the web survey. The survey was conducted in the period from January to April 2019. A total of 370 completed questionnaires were collected. After selective analysis, responses that were not completely filled were excluded from further analysis which ended with 314 fully filled questionaires. The collected data has been statistically processed and analyzed, and the most important results are presented below.

3.1 Characteristics of the sample

The selected sample consists of highly trained logistics staff that work in different companies and in different positions. About 50% of the respondents are employed in international logistics and freight forwarding, while others work in distribution and domestic transport (23% of respondents), production (19,75%), contract logistics – 3PL (16,61%), retail (11,6%) and other industries (8,5%). When regarding the size of the company, most of the respondents are employed in companies with over 1000 employees

(34,2%), followed by companies with 150-300 employees (27,6%). The smallest number of respondents are employed in companies with 600-1000 employees. From the aspect of the position of the respondents, three groups are dominant: Logistics Manager (18%), Transport Manager (17%) and Logistics Assistant (13%). Answers to question related to the years of work experience of the respondents showed that over 60% of the respondents have 3-7 years (35,1%) or 7-15 years (31%) of working experience.

3.2 Recruitment and retention of the logistics workforce in Serbia

Questions from the second group were intended to examine the recruitment, retention and fluctuation of labor in logistics. When it comes to employment, almost half of the respondents (49,5%) did not wait for the first job, around 31% waited up to 6 months, while the rest waited over 6 months (figure 3). When it comes to fluctuation, then the results show that he vast majority of respondents generally worked in 1-5 companies (as much as 95,9%), while the remaining 4,1% worked in over 6 companies. On the basis of the results of this question, it can be concluded that the majority of respondents worked in 3-5 companies (37%). For over half of the respondents, the period of 1-5 years is the average time spent in one company, with a dominant period of 1-3 years (37,6% of respondents).

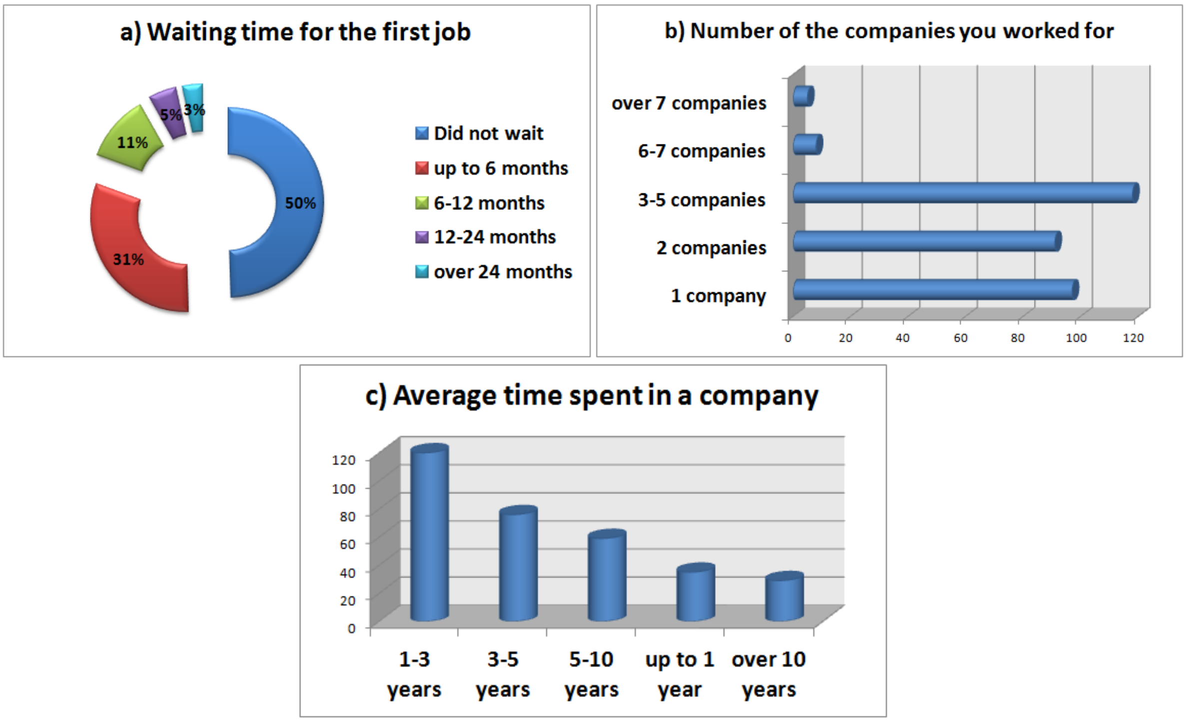

Figure 2. Recruitment and retention of logistics personnel in the Serbian market

These results show the high demand for logistics workforce in Serbia. These facts are confirmed by the official data of Infostud, the most famous advertising portal for jobs on the Serbian market. According to these data, it was established that in 2018 there were 829 ads related to management positions in the field of logistics (logistics managers, referents and dispatchers), which is 2,2 ads each day. In addition, there were 1455 ads for warehouse operations, forklift trucks and 1521 ads for transport workers (drivers, couriers, etc.). When it comes to estimating the annual growth in demand for logistics experts, the majority of respondents (over 65%) said that in the coming years the growth rate would be 3-10%.

In addition to fluctuations between companies, the survey examined the movement of staff within a company (figure 3). Over half of the respondents indicated that they changed 1-2 positions (63,64%), where most of them remained in one position for about 2 years (54,9%) and 2-5 years (35,1% of respondents). The main reasons for changing the company were the impossibility of promotion (49,22%). Beside this, second reason is related to the salary (44,83%). Two reasons that were present in less than 100 respondents, but which are still significant are lack of vision (29,15%) and poor interpersonal relationships (27,27%). When considering the average salary, given that this question was not mandatory, 294 respondents answered. Out of the total number of respondents, two dominant answers were singled out: from 700-1000 € (28,9% of respondents) and 1000-2000 (27,6%). The smallest number of respondents has a salary over 3000 € (only 3,4%).

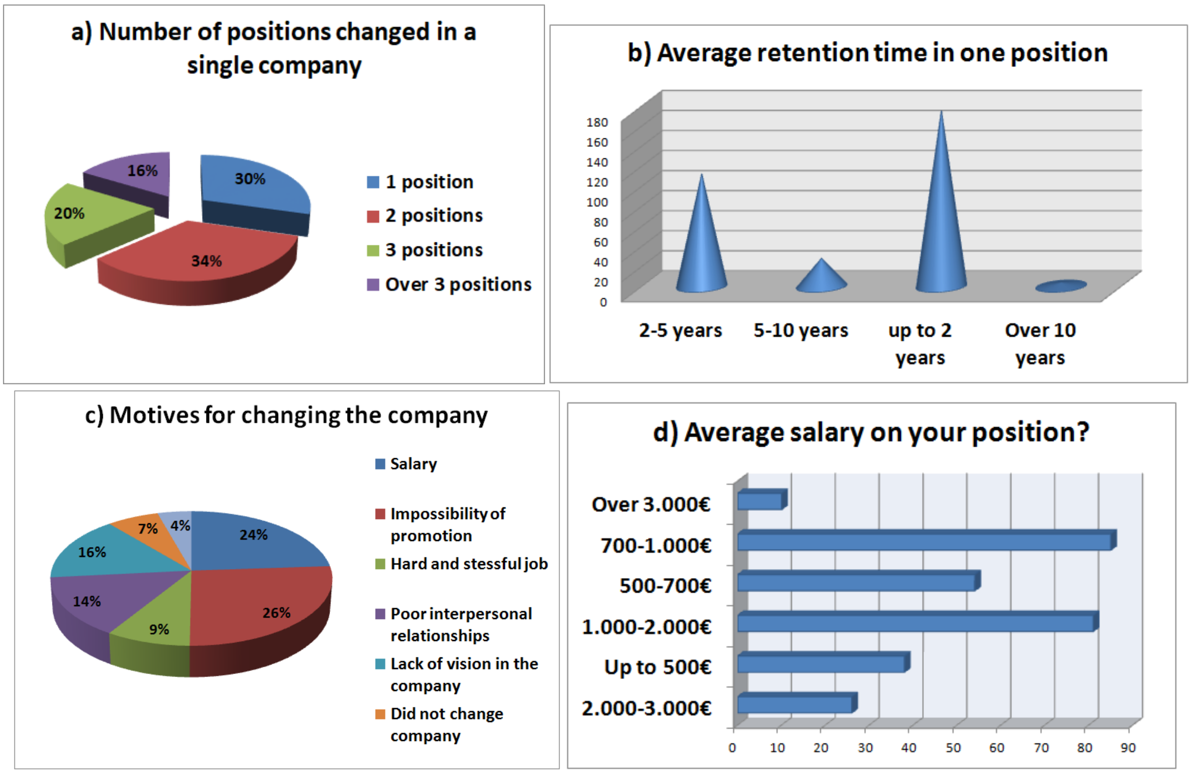

Figure 3. Fluctuation of the workforce in logistics sector

3.3 Education and competencies of the logistics workforce

The next group of questions concerned the establishment of education and the necessary skills of logistics workforce in Serbia. Of the total number of employees in logistics 66,8% of the respondents graduated from the Faculty of Transport and Traffic Engineering, of which 42,6% Department for logistics, followed by the Faculty of Economics (8,5%), Faculty of Technical Sciences Novi Sad (7,2%), Faculty of Organizational Sciences (5,3%) and other faculties and schools (15,4%). Only Faculty of Transport and Traffic Engineering, Logistics Department, educates logistics workforce with all the competencies in logistics and supply chains, while other faculties mainly focus on other competencies and have a few logistics subjects. In order to determine how much companies invest in employee development, a question regarding the number of external or internal trainings that the respondents went through in their careers were asked. It was found that the vast majority of 81,5% of the respondents had between two and more than five trainings, while the rest of 18,5% did not have any form of training.

When it comes to the knowledge necessary for successful job performance, the majority of respondents stated that professional logistics knowledge, business communications, foreign language, management and organizations are crucial (figure 4).

Which competencies are expected from students when they graduate	Number of respondents (%)
Interest and motivation for work	82.8
Knowledge of basic computer programs	80.6
Knowledge of foreign language	80.3
Personal qualities	74.9
Communication skills	64.9
Practical skills	47.6
Professional knowledge	43.6
Other	5.3

Figure 4. Necessary competencies of logistics workforce

When respondents were asked about what would, in their opinion, contribute to the improvement of the competencies of logistics experts, the majority of respondents mentioned the innovation of curricula (74,3%), better cooperation between faculties and companies (67,7%) and internal and/or external employee training (51,7%). The main characteristics and competences expected from student when they finish their studies are interest and motivation for work, knowledge of computer programs, foreign language skills, personal qualities (team work, behavior, etc.) and communication skills. The views on professional practice were examined where paid scholarship emerged as a dominant way of organizing the practice, which was chosen by 74,3% of the respondents, followed by mentor's work (67,7%) and defined practice program (51,7%). From the aspect of the duration of the practice, dominant responses relate to full-time work for 3-6 months a year (37,3%) and full-time work for up to 3 months a year (28,2%).

4. CONCLUSION

Based on the analysis carried out, it can be concluded that there is an evident lack of labor in the world with the necessary logistics competencies and skills. In addition to significant workforce potential, this problem has been seen in the Serbian market in recent years. This is due to two key causes. The first refers to increased economic activity and the arrival of foreign companies that generate more and more demands for logistics. The annual needs for logistics workforce largely exceed the number of trained personnel. Another problem is the openness of the market and the departure of human resources abroad, especially the EU countries, where wages are significantly higher and working and living conditions are better. In addition to the insufficient number of young educated staff, the problem also arises with the existing workforce that is not adequately educated and has no competencies that require new technologies and modern ways of doing business. In certain positions in logistics, personnel do not have appropriate formal logistics education or the necessary logistics skills. The potential for employment in logistics is limited by the low reputation and status of this sector in the economy and society. This does not attract young enough when choosing a career. It is necessary to improve the image and position of logistics activity. The nature of work, working conditions and advancement, low wages and low social status are just some of the reasons for insufficient interest in the logistics profession.

Solutions for the successful development of this extremely important profession must be sought through the close collaboration of business companies, educational institutions and the public sector. These are three key parties that make up a triangle in which a synergistic effect can be achieved which will result in a greater number of experts with appropriate logistics competencies and skills. Businesses must make more efforts to create conditions, work environment and ambience to attract labor, but also to work on career guidance and advancement, external and internal training, and greater motivation for the employed. Universities and other education institutions need to adapt their curriculum to the real needs of the market as much as possible and to enrich the theoretical and systematic knowledge with more practical skills. The public sector and the competent state institutions must pay more attention to the creation and development of logistics staff, through concrete support to formal and non-formal education. In addition to investing in infrastructure and regulation, it is necessary that the state invest more in the education and development of human resources in logistics and supply chains. In future researches, it is necessary to increase the sample, as well as to determine the degree of correlation between certain factors.

ACKNOWLEDGMENT

This paper was supported by the Ministry of Education, Science and Technological development of the Republic of Serbia, through the project TR 36006.

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COST OF QUALITY IN DISTRIBUTION LOGISTICS

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Abstract: *The task of logistics in the field of sales and distribution of the products is to achieve the highest quality of service with as lowest cost as possible. These are two conflicting goals that need to be explored and tackled together with the tendency to come up with an optimal solution. The quality of logistics services is directly linked to costs through two key perspectives. The first refers to the good quality costs, which involve investing in preventive solutions, such as implementation of quality standards, planning, management, control and quality assessment. The second perspective refers to the bad quality costs, which are the consequence of nonconformance, internal and external errors. This paper provides a review of different approaches and models for determining the cost of quality, such as: PAF model, opportunity cost model, process cost model, ABC model and Taguchi's loss function. The procedure for determining costs in the area of distribution and delivery of the products from the distribution center to the stores is presented. The methodology in this paper includes: mapping and process analysis, identification, quantification and analysis of the quality costs.*

Keywords*: Cost of Quality, distribution, logistics, PAF model*

1. INTRODUCTION

Distribution process is a process that requires significant resources, and therefore can significantly affect the quality as well as the costs arising from that quality. These costs arise even before the distribution process itself (preventive costs), but also after the distribution process (external errors). In addition, the costs in this process arise in order to provide a flexible, accurate and reliable service. For these reasons, for companies that are monitoring and trying to minimize total costs, quality costs should be one of the key parameters.

The aim of this paper is to present the most frequently used models for determining the cost of quality in the distribution process. The Cost of Quality (CoQ) can be defined as the cost of conformance and non-conformance, ie. the cost that is incurred to match the quality of the service with pre-determined requirements and standards. In addition, the cost of quality in the broader sense means the cost that has been incurred to achieve and

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maintain the appropriate quality, but also the cost resulting from poor quality management, in order to increase customer satisfaction. It can be said that the models which take into account the cost of quality are more complete, since the likelihood of product quality mismatch in real situations is more likely, causing repairs, rework or replacement of the product. For this reason, in this paper, emphasis on such models is given. Based on the literature, it can be concluded that there are models that have a good basis for calculating costs, but they still do not have a formulation, and for this reason they are rarely used in practice but are present in the literature. Those models are opportunity and process cost models.

The paper consists of two parts. The first part gives an overview of the different approaches used to determine the cost of quality. The second part relates to determining the cost of quality in the case of the distribution process.

2. DIFFERENT APPROACHES FOR DETERMINING COST OF QUALITY

Costs of quality in the distribution process can be considered as one of the key performance indicators, through which the efficiency of the process in terms of financial indicators is determined. The aim when implementing models that, when calculating costs, take into account cost of quality is to maximize quality while simultaneously minimizing costs (Andrejić et al., 2018). The cost of quality can be defined differently according to some authors and institutions, and some of them are given below in order to better define the cost of quality. British Standards Institute defined the cost of quality as a sum of cost incurred as a result of prevention and appraisal, as well as the costs of internal and external errors. Mashowski and Dale (1998) defined this cost as a sum of the costs of conformance and non-conformance, where the cost of conformance with the required quality includes: costs of preventing the production of products with poor quality, while the cost of non-conformance includes repair costs or costs of products that did not meet the required quality. A similar definition was given by Srivastava (2008), which defined the cost of quality as a sum of all costs (along the entire supply chain) that arose to prevent the poor quality of the products and meet the required quality. According to Crosby (1984), the total cost of quality is about 20-35% of the sales of production companies, while according to Feigenbaum it is about 10% of the revenue and about 30% of the total production costs (Douri et al., 2016).

Shiffauer and Tomson (2006) classified CoQ models in the following four categories: P-A-F or Crosby models, opportunity cost model, process cost model and ABC approach. Most models that take into account CoQ when calculating costs in the supply chain are based on the P-A-F classification (prevention (P), appraisal (A) and failure (F)). Prevention costs include costs arising from the planning, implementation and maintenance of a quality management system aimed at ensuring compliance with the required quality. In other words, these are costs that arise in order to prevent errors. Appraisal costs are the costs related to checking and defining the level of compliance in order to achieve the required quality. Costs of errors can be divided into internal and external. Internal failure costs arise when there is a mismatch of the service with the pre-defined level of quality, before the service reach customer. External failure costs include costs arising from a service mismatch with the pre-defined level of quality which is detected by the customer. This group of costs is the most dangerous for the company, since it can result with a loss of a customer, as well as additional costs. Also these costs may have bad impact on the reputation of the company. For this reason, companies should make the greatest efforts to prevent the occurrence of these costs. Given the popularity of this approach to the cost accounting in the literature, a number of models have emerged that represent the modification of the basic P-A-F model. Aniza et al. (2013) applied a hybrid P-A-F model which beside this model also relied on the process cost model. In this approach, the costs are divided according to P-A-F classification, with the difference that each of the categories is further divided into unit costs of certain activities. The sum of all unit costs represents the total cost of quality. In addition to this modification, in the literature another modification was identified, which is based on the basic P-A-F model, but which beside basic cost categories, also takes into account recycling costs. These costs are taken into account considering that recycled products can be used in order to get a new product. In addition to the cost of recycling itself, this model also takes into account the cost of product collection, vehicle costs (fixed and variable), labor costs, container costs, etc. In addition to the aforementioned factors, the type of recyclable material also affects recycling costs. The recycling process can be carried out by the supplier or the factory that is engaged in production. If the recycling process is done in a factory then the costs consist of three types of costs: the cost of purchasing used products, as well as the cost of transport; the cost of recycling, consisting of the costs of sorting, inspection, restoration and disposal of waste; re-production costs (Obied-Allah, 2016). Beside the visible ones, which are the basis for calculating the cost of quality, it is often forgotten at the so-called hidden costs that can be significant and have a negative impact. In addition to hidden costs of quality, hidden costs include costs due to loss of profit, costs associated with user dissatisfaction, which in the worst case can lead to customer loss, as well as socio-economic costs. There are two ways to measure and monitor the cost of quality: temporary measurement and monitoring (when fewer workers are assigned to follow these costs over a specific period of time) and systematic continuous measurement and cost monitoring (where all employees are required to report). The first way is useful when resources and time are limited, but is therefore less detailed, while the other way requires a lot of time and resources, but is more detailed (Abramsson et al., 2006).

Many authors consider opportunity cost as the cost of losing a customer due to poor quality of the provided service. These costs are also considered indirect, i.e. hidden costs. Other authors who studied these costs came to the conclusion that these costs affect more than 83% of total loss in revenue and about 50% of profit loss (Douiri et al., 2016). According to Sandoval-Chavez and Beruvides (1998) opportunity cost is a cost that can be broken down into three groups: insufficient capacity utilization, inadequate product handling and poor quality of delivery (Wang et al., 2010). The cost of quality is defined as lost income and profit that is not realized, i.e. as an opportunity cost. Although this type of cost is often forgotten during calculation, some authors consider that these costs must be taken into account and consider that, in addition to the cost of prevention, appraisal, and errors in the P-A-F model, this cost should also be an integral component of the model. Beside missed sales, some of the authors, as opportunity cost also include permanent loss of customers due to poor quality of the product or service. Freiesleben divided opportunity cost into the following components (Ayati, 2013):

1) lost sale,
2) good will and guarantee to the customer,
3) the delay time due to the correction of the error,

4) slowing down the process due to inspection,
5) overcapacity due to a specific sales target,
6) cost during the management of disruptions during the realization of the service.

Process cost model consists of the cost of conformance and non-conformance of individual processes. The main goal of this model is to calculate the cost of quality of each process in order to reduce or increase the investment cost of prevention for each process (Douiri et al., 2016). In order to calculate the cost of the process, it is necessary to determine the input elements, the activity generating the costs (production, processing, etc.) and the output elements. Although the process cost model helps in determining and analyzing the cost of quality, it's use is not widespread.

In addition to these models, an approach developed by Genichi Taguchi, which was named after him and which refers to the loss function, is also present in the literature. This method combines engineering and statistical methods with the aim to rapidly improve quality and reduce costs. The three ideas behind this approach are: costs can not be reduced without affecting the quality, quality can be improved without increasing costs and reducing variations affect cost savings, which will directly affect performance and quality improvements (Teli et al., 2014). Beside these ideas, Taguchi approach is based on two basic facts, which are: loss due to insufficient quality increases with increasing deviation from the nominal value, for which "zero defect" is achieved and a high level of product quality is provided during the design stage, not in production.

3. DETERMINING THE COST OF QUALITY IN DISTRIBUTION PROCESS

Determining the cost of quality requires the application of a special procedure that includes: analysis and mapping of the processes, identification and evaluation of cost of quality (Kilibarda, 2016).

3.1 Analysis and mapping of the distribution process

The distribution process, figure 1, represents the connection between the demand and the delivery of the items to retail objects. From the perspective of necessary people as well as resources, distribution is one of the most demanding processes. The whole process begins with the demand for an item by stores. After the order is placed and after checking inventory, the order is processed after which a picking order is issued so that picker can start with the process of preparing goods for the stores. After this process the picker performs picking process. Before the distribution, it is necessary to carry out the control of the ordered goods (in order to determine whether a quantitative or qualitative error has occurred), after which, if everything is fine, the goods are packaged and loaded into the vehicle in order to deliver them to the stores. After distribution, the goods are unloaded and handed over together with the documentation to the store manager.

Figure 1. Flow chart of the distribution process

3.2 Identification of the cost of quality

Beside quality costs that are specific to the distribution process, during identification, other costs of quality that enable the realization of this process have been identified as well. All costs are divided according to the P-A-F classification and shown below. In addition to the identification, the source of the costs was determined. The list of the described costs is shown in table 1.

Table 1. Identification of the cost of quality

Cost category	***Cost type***	***Source of the cost***
P	Costs of standard maintenance	Quality sector
P	Training costs associated with the standard	Quality sector
P	Costs of preventive maintenance of assets and equipment	Maintenance sector
P	Costs of establishing and maintaining working procedures	Quality sector Distribution sector
P	Costs of planning the processes in the distribution (sales, ordering, transport, warehouse, delivery)	Distribution sector
P	Costs of quality assurance in the distribution process	Quality sector Distribution sector
A	Costs of monitoring and controlling the distribution process	Distribution sector
A	Customer audit costs	Quality sector
A	Costs of quantitative and qualitative control	Warehouse
A	Costs of internal checks	Quality sector
A	The cost of tracking the shelf life of the product	Warehouse
IF	Costs of errors in processing the order	Order processing sector

Cost category	***Cost type***	***Source of the cost***
IF	Costs of errors in picking order	Order processing sector
IF	Costs of picking errors	Warehouse
IF	Costs of damaged items during picking	Warehouse
IF	Costs of repicking due to damaged products	Warehouse
IF	Costs of filing documents (invoice, bill of lading, etc.)	Shipping department
IF	Costs of invoicing errors	Finance
IF	Costs of errors during the loading of goods	Warehouse
IF	Costs of transportation errors	Transport
IF	Costs of errors during unloading of the goods	Transport
IF	Costs of writing off and destroying goods	Warehouse
EF	Costs of errors during the handover of the goods	Store
EF	Costs of errors in documentation and/or quantity of goods	Store
EF	Costs of complaint processing	CRM sector
EF	Costs of expiration of the product	Store
EF	Costs of product replacement	Distribution sector
EF	Costs of returning the wrong products	Transport
EF	Costs of emergency delivery	Transport
EF	Costs of penalties due to delayed delivery	Distribution sector

3.3 Evaluation of the cost of quality

When it comes to estimating and quantifying the cost of quality, then it is necessary to bear in mind the three groups of costs: direct cost of quality, hidden cost of quality and opportunity cost. Direct costs include costs of: prevention, appraisal, internal and external errors.

The cost evaluation was carried out for two scenarios, which can actually occur in the distribution system (table 2). The first scenario involves a fully implemented quality and prevention system through implemented standards and procedures for process realization, where most of the cost of quality is related to prevention and appraisal activities. Up to 70% of the total direct costs of quality fall to these costs. The remaining 30% of the costs relate to internal and external errors, which is significantly less because there is not too much inefficiency in logistics processes and activities. The second scenario refers to a situation where there is no established quality system in the distribution process, and the costs of prevention and appraisal are relatively small and range up to 15% of the total cost of quality. However, in this scenario, the costs of internal and external errors are extremely high, which is a consequence of the non-conformances that exist in the process of distribution of goods. These costs reach up to 80% of the total cost of quality in distribution process.

Table 2. Share of certain categories in total cost of quality

Cost of Quality category	***Scenario 1***	***Scenario 2***
	Share in total Cost of Quality (%)	***Share in total Cost of Quality (%)***
Prevention costs	45	5
Appraisal costs	25	10
Internal failure costs	10	30
External failure costs	20	55

Bearing in mind the above mentioned cost of quality structure, it is justified to ask what is the level of quality that will ensure minimal cost of quality in the product distribution system. Figure 2 gives a graphical representation of the movement of costs of prevention and costs of errors, as well as total costs. Based on the shown figure, it can easily be concluded that the total costs are minimal at the intersection of the prevention costs and costs of the failures. This can be considered as an optimal level of quality that needs to be maintained in a single distribution system.

Figure 2. Determining the optimal level of quality in the product distribution process

In the process of quality planning, it is necessary to determine the balance between investment in prevention cost and costs arising from internal or external errors. Namely, as can be seen in figure 3 with increased costs caused by preventive measures as well as appraisal, the cost of errors is reduced, which leads to additional profit.

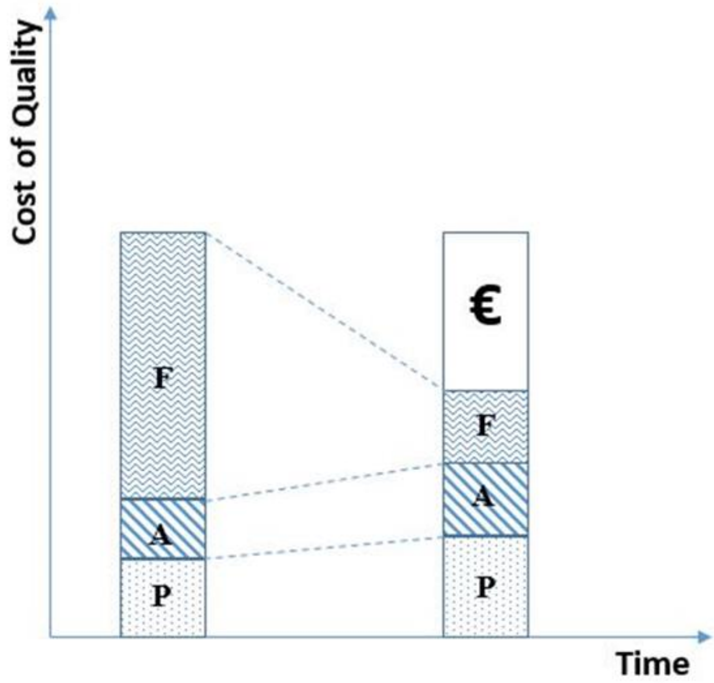

Figure 3. Allocation of the cost of quality

A detailed quantification of direct costs of quality requires precise determination of resources engaged, time needed for performing certain activity and what are the costs of engaging resources for each activity in the prevention and appraisal process. When observing errors, it is necessary to precisely determine the size of the error and engaged resources in order to eliminate that error. It is particularly problematic to quantify the cost of external errors, which can have far reaching consequences on the product distribution system. Unlike direct costs of quality, it is much more difficult to estimate and quantify the so-called hidden and opportunity costs of quality. Hidden costs of quality can also be linked to prevention, appraisal, internal and external errors. As they are not directly visible and linked to the resources involved, a special procedure for assessing and quantifying these costs needs to be developed. Opportunity costs in the distribution system relate to loss of opportunity and sale due to non-conformance and low level of quality of provided service, lack of goods in stock, customer dissatisfaction, etc. These costs may have negative impact on the distribution system and need to be kept under control. However, these costs are very difficult to quantify, measure and track. Opportunity costs are often associated with external errors in the distribution process.

4. CONCLUSION

In the distribution process, the cost-quality ratio is crucial. Costs directly affect the price of service and business efficiency, while the quality affect customer satisfaction and loyalty. Reducing costs and improving quality can be viewed as opposing goals. However, it is necessary to look for solutions that will provide the highest quality of product delivery with as little as possible total cost. This is certainly not an easy task and requires the development and application of a comprehensive methodology and procedure for determining, measuring and tracking cost of quality. In this paper, the authors tried to examine in more detail the problem of cost of quality in the product distribution system and perform rough identification and cost estimation.

The aim is to develop concrete procedures and models for determining, measuring and monitoring cost of quality in future research and papers. It is particularly important to quantify, analyze and monitor the costs that are consequence of internal and external errors in the distribution process. Errors are the result of certain solutions and procedures for the operation of logistics activities, while the causes of errors can be different (spatial, organizational, technical, technological, information and personnel). The cause can be in one process or in multiple processes, while the error is noticed in completely different process. For this reason, it is necessary to determine: the cause of the error in order to eliminate or reduce its negative impact, the cost of the error that represents the measure of the weight and size of the error as well as the negative impacts caused by the error. It is also necessary to bear in mind the impact of the quality of the delivery on the satisfaction of the customer. A lower level of customer satisfaction, which is a consequence of poor quality, results in high costs for the company through lost income because of customer loss, but also through large investments in promotion, marketing and sales efforts.

ACKNOWLEDGMENT

This paper was supported by the Ministry of Education, Science and Technological development of the Republic of Serbia, through the project TR 36006.

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BARRIERS TO IMPLEMENTATION OF AUTOMATED COMMERCIAL VEHICLES IN GOODS DISTRIBUTION

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Abstract: *Development of automated vehicles (AV) has gained additional impetus due to a significant lack of professional drivers throughout Europe and America in recent years. Other latent problems are vehicle overloading, whose responsibility is the proper/inadequate cargo distribution and securing in the AV cargo compartment and its access control, how the freight loading/unloading/reloading will be carried out, as well as legal and financial liability in case of vehicle stability loss due to improperly distributed and secured cargo. There is a problem of allocating responsibility in case of AV malfunction or breakdown in operation, as well as who will generate requirements for vibration or noise related AV maintenance. Will it be necessary to change existing Incoterms rules or introduce new ones? Potential AV implementation barriers will be identified and reviewed in this paper, questions raised and suggested possible solutions to those issues, as well as defined potential supply chain actors' liability when involving automated vehicles.*

Keywords*: automated commercial vehicles, logistics chain, barriers, responsibility, road safety*

1. INTRODUCTION

Currently, automated vehicles (AVs) are increasingly gaining more significance every day and many companies are getting involved in their development in order to enhance road safety (accidents reduction), reduce congestion (total travel time reduction), as well as solve the problem of professional drivers' shortage in the commercial transportation sector. On the other side, their intention is to occupy the leadership position in this growingly innovative field. AV technology could make a major impact on lowering travel times, delays, accidents, congestions, energy consumption, as well as global environmental pollution caused by road transportation activities (Marchau et al., 2018). According to Fraedrich et al. (2018) the primary focus is the development of AV technology, as well as the effects on traffic flow, road safety, traffic congestion, exhaust gas emissions, parking problems and land use (adjustment in lane widths and layouts, removal of signage and need for drop-off and pick-up areas). Fagnant & Kockelman (2015) are among rare authors who consider AV application in freight transportation and

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benefits deriving from it. Besides companies dealing with AV development, these vehicles have drawn the attention of research community, planning practitioners and policy makers (Fraedrich et al., 2018).

Although it is not evident, many AVs are presently cruising on the roads worldwide, despite the fact that they are still not fully automated which is the ultimate intention. Today's AVs require drivers' presence and engagement since driverless vehicles are still not legally permitted in many countries, road infrastructure and their environment is not fully prepared for them and they are not operable in all weather conditions. AVs development rely on advanced driver assistance systems (ADAS), such as Forward Collision System, Adaptive cruise control, Automatic braking, Automatic parking and similar. Nevertheless, some ADAS have disclosed adverse impact on road safety since drivers relax and don't pay (sufficient) attention to traffic situations because they rely (too much) on these systems. In that way, they are exposed to additional unnecessary risk, which was not the case before the existence of these systems (Robertson et al., 2017). To better understand the levels of driving automation, Society of Automotive Engineers (SAE) defined the features of six levels of automation from no automation at all (level 0) to full automation (level 5) (SAE, 2018). These levels of automation and what they include are presented on figure below (Figure 1.).

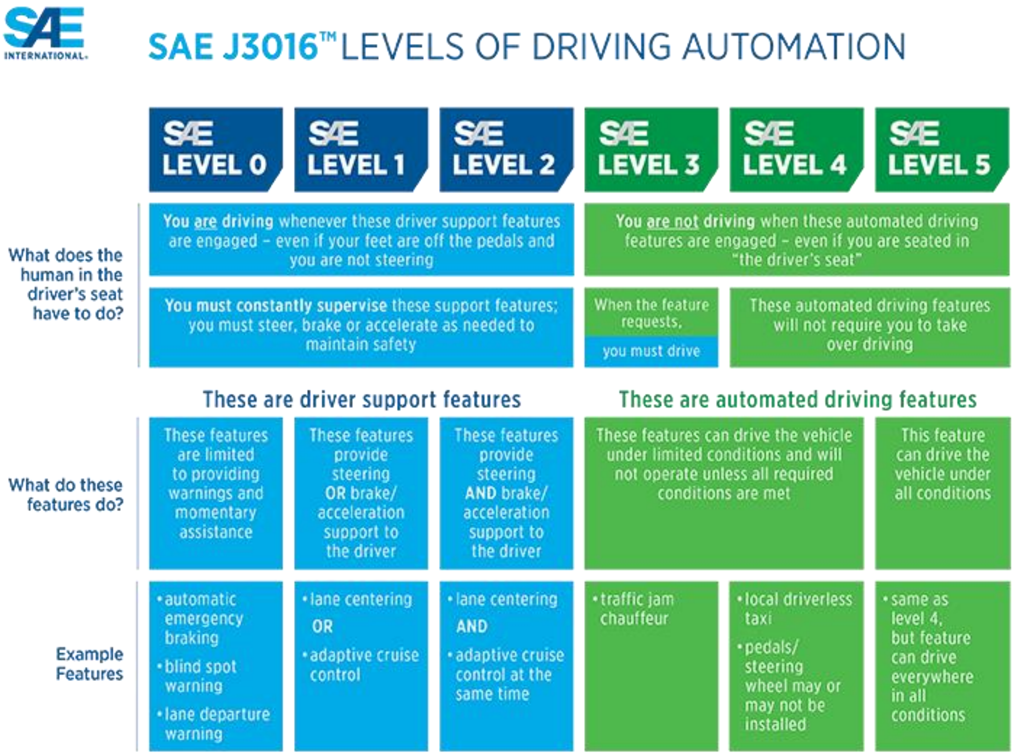

Figure 1. Levels of driving automation (SAE, 2018)

As it is shown on figure 1, levels from 0 to 3 require drivers' presence and some degree of engagement, so the driver (must) operate the vehicle in all times or certain moments. Namely, first three levels (levels 0, 1 and 2) require constant driver engagement in vehicle operation, while the fourth level (level 3) requires vehicle operation only when necessary and when vehicle requests it from the driver. Levels 4 and 5 are almost the same, with one key difference: level 5 vehicle can operate autonomously in all operating conditions, such as weather, visibility, and road conditions, so they have no impact on efficient vehicle operation. Even if completely AV could independently operate without driver's presence and is able to overcome all the obstacles, some barriers still arise and represent setbacks to their efficient implementation in existing commercial transportation.

The paper is structured as follows. Chapter 2 contains previous research about AV application and identified issues in this field. Chapter 3 refers to the obstacles occurring an efficient AVs implementation in the transportation system, especially in view of commercial transportation, while the conclusions and future research are given in Chapter 4.

2. PREVIOUS RESEARCH

Authors were until now dealt with different AV implementation problems. In that sense, some authors consider the link between parking policy and automated vehicles (AV parking problem) (Millard-Ball, 2019), some of them consider adaptation of AV users behavior on non-fully automated vehicles (Robertson et al., 2017), then effects on urban planning and built environment (Fraedrich et al., 2018), high price of AV vehicles and how to overcome this barrier (Masoud & Jayakrishnan, 2017), Crayton & Meier (2017) consider the influence of AV on public health, while Sraub & Schaefer (2018) in their paper deal with users interaction on transport network, including AV, other drivers, pedestrians, bicyclist. Besides above mentioned, Sraub & Schaefer (2018) define policy issues regarding responsibility of control allocation, communication of AV with pedestrians and bicyclist, the courtesy problem and communication with other drivers and the second vehicle problem.

Fraedrich et al. (2018) imply that AVs not only have influence on vehicle flow and usage, but that they have a lot bigger importance, thus the authorities should make plans and strategies to implement and approve this new technology. Regarding this Crayton & Meier (2017) emphasize that for each level of automation new policy implications occur and there is a constant need to adjust transport policy to AV. Different policy makers are extremely interested in wider usage of these vehicles, but development of transport policy in this field is tied to many uncertainties regarding evolvent and application of AV (Marchau et al., 2018). According to Sraub & Schaefer (2018), it is almost impossible to establish or make transport policy regarding AV since these vehicles are liable to significant changes which could have impact on creating the transport policy. In that sense the authors of this paper quote that it is necessary to pay attention to other obstacles which will definitely exist after AV implementation (when the obstacles in development of AV technology are overcame), especially in case of fully automated vehicles. In accordance with Sraub & Schaefer (2018) also in this paper the aim of the authors is to give proposals, not only to policy makers, but also to manufacturers (researchers) of AVs, that should be taken in consideration in order to define necessary standards, policies and AV construction, so that AV could be easily implemented in existing transport system. In addition to that some procedures need to be defined and the focus should be particular parts of transport policy which are not closely connected to AV technology and their impact on the other traffic participants (other vehicles, bicyclist and pedestrians), environment, traffic congestion, etc.

Through extensive literature review which refers to AV, it is notable that most papers are focused on individual passenger cars, but only small number of papers are dealing with commercial AVs. The authors consider that further attention must be paid to the commercial transportation sector since it is one of the sectors which AV implementation will have a major impact on. This is due to a significant professional drivers' shortage throughout Europe and America in recent years, as well as because the opportunity for transport companies to achieve additional profit by not engaging drivers (no labor cost), widening distribution time-window, eventually enabling 24/7 deliveries. Also, vehicle operation will not be limited as currently by drivers' availability in the sense of working hours, driving time, rests and similar.

Of course, for this transition toward fully automated fleets to run smoothly and efficiently, without major problems and obstacles, it is necessary to develop a technical logistics system in transportation and logistics companies. In that sense, different barriers have been identified and considered in the next chapter in order to be prepared for the eventual implementation of AVs in the supply chain.

3. BARRIERS IN THE GOODS TRANSPORTATION SECTOR

Hereafter the authors present an overview of barriers and risks that may arise in goods transportation by AVs. Some of the outlined barriers require precise allocation of duties, responsibilities, costs and losses of different participants in logistics chain.

Barrier 1: vehicle cargo problem

One of many problems which should be solved is vehicle overloading aimed at increasing operator's competitiveness and profit at the expense of road safety. Besides technology development, which is currently the most significant obstacle, compliance with EU legislation in force regarding motor vehicles appears as a barrier to smooth AV implementation. Directive (EU) 719/2015 defines that by May 27, 2021 critical vehicle (and vehicle combinations) categories regarding potential infringements of maximum authorized weight and/or axle load limits must be identified, in order to facilitate their enforcement and ensure their better compliance with these rules. In that sense, there are two possible options: automatic systems embedded into the road infrastructure (for dynamic vehicle weighing) or on-board weighing equipment (sensors) installed in commercial vehicles. For economy reasons, since the implementation of smart tachographs, equipped with Dedicated Short-Range Communication systems facilitating remote enforcement, is envisaged for mid-2019, it is also expected that new commercial vehicles will be equipped with such on-board weighing equipment (sensors), integrated with tachographs. Aforementioned equipment (sensors) must be accurate and reliable, fully interoperable and compatible with all commercial vehicle types.

One of possible solutions to this problem would be fitting AVs with sensors that will measure and display axle load though providing a direct insight into this. In that sense the personnel responsible for loading could have valuable information on the current state of axle load and the remaining maximum quantity of goods to be added to each individual axle and therefore to dispose of an on-board cargo distribution tool. If the maximum permissible axle load is exceeded this system could inform the user via a visual or acoustic warning signal on each individual axle, and how the cargo should be rearranged (where to). AVs should be fitted with a provision for identifying, monitoring and protection against tampering, manipulations and fraud. Of course, a serious concern should be given to prevent possible manipulations through hacking the AVs and programming it not to register excessive axle loads, or setting the axle load on a higher weight value than designed or prescribed. In terms of remote (short-range) enforcement of AVs in order to prevent software manipulations and tampering attempts.

If a manipulation is unambiguously determined and identified, e.g. if AV on-board system is hacked, the question is who will be held responsible for this manipulation and who will cover the incurred fines and expenses? According to authors' opinion, this obligation of AV monitoring and therefore responsibility should lie on the company the AV owner/user (vehicle/fleet responsible person). Mainly because this responsible person should take care of the whole vehicle fleet, both if the AV are parked in the company premises or they are presently engaged in goods transportation.

Considering that at the highest level of automation the presence of a driver will not be necessary (and therefore not foreseen), the issue will be: who will take responsibility for the proper/inadequate cargo distribution and securing in the AV cargo compartment, especially when the maximum authorized axle load will be exceeded identified in roadside checks. Also, the problem of cargo compartment access control (its entirety or some part of it) arises, as well as how the freight loading/unloading/reloading will be carried out, especially in cases where one vehicle supplies multiple users (city distribution). Another problem of legal and financial liability in case of vehicle stability loss due to improperly distributed and/or secured cargo particularly when it causes a road traffic accident, cargo / vehicle damage, or human fatalities.

Those problems can be overcome by constructing the AVs in such a way to limit access to cargo compartment(s)/units only to authorized persons, especially in case of a city distribution or a delivery to multiple users. In that sense, if there were irregularities in cargo loading / unloading / reloading, the responsible person should be the last one that had the access to the precise cargo compartment(s).

The question of cargo safety during transportation should be also considered – what happens and who is the responsible if the cargo is damaged during transportation. Whether liability is on the last person who has access to cargo compartment and how to prove that the cargo wasn't secured properly. Therefore, the AV and/or cargo compartment should be equipped with additional equipment, monitoring systems or sensors in the cargo area. With appropriate facilities it could be proven why, how and in what moment the cargo was damaged. It is essential to determine what caused the damage: was it inadequately arranged or secured cargo or some segment of AV operation caused it, such as inadequate acceleration, insufficient braking, deficient maneuvers, etc.

In terms of cargo security, thefts should be considered and prevented, as far as possible. Since this is a common problem even when the drivers are in or around the vehicle – thefts happen. AVs are programmed to upgrade road safety and therefore will stop if the road is blocked, someone put barricades, or another vehicle stopped in front of it. All obstacles will prevent AV's passage and make it vulnerable to "road pirates". In cases when AV registers unauthorized or illegal access to its cargo compartment(s), it should notify the police and the company owner/user immediately and record the whole event with camera(s) or similar monitoring provisions. Nevertheless, for cases of theft, the company should have cargo insurance and cover the expenses to cargo owners and transport service users.

Barrier 2: vehicle maintenance and breakdowns

There is a problem of allocating responsibility in case of AV faults, failures, malfunctions or breakdowns in operation, for vehicle towing, traffic congestion and eventual related road accidents? Meanwhile, in the framework of AV maintenance and repair, the following question arises: (in lack of driver/operator) who will generate requirements for vibration or noise related AV maintenance, aside from irregular or legally inadmissible vehicle operation, such as inefficient acceleration, insufficient braking, etc.

As it's defined and planned so far, it is anticipated that AVs will be failsafe and technologically advanced enough to perform complete start-up and continuous self-diagnostics to determine (present or imminent) faults, failures, malfunctions or breakdowns, as well as if it realizes so, to determine could they affect operation or road safety (of other road users). According to this paper authors assuming that AV will be far better fitted with ADAS than current vehicles, it is necessary for AVs to have such real-time diagnostics system to monitor and predict imminent failure(s) of AV systems, components or elements, so that at the adequate moment leaving safely the traffic flow without compromising other road users. In addition to systems that would constantly monitor the condition(s) of AV and all of its components, there is also the possibility to install additional back-up systems designed to serve as emergency replacement if main system fails. This would of course drastically increase the cost of AV, but when it comes to human lives and injuries, this increased price definitely should not be a limitation criterion. AV should pass to a back-up system (if available), override the faulty function, restart software, allow remote diagnostics and/or troubleshooting, reach road assistance or contact stationary maintenance service center and/or repair workshop. This is very important when considering the beginning of AV implementation, since a sudden breakdown on the road can affect drivers of other (non-automated) vehicles and eventual accidents could occur caused by untimely or inadequate reaction of involved road users. Just imagine the consequences of high-speed driving behind and close to an AV on the highway and it experiences a sudden fault, breakdown or stop due to a failure.

Moreover, authors consider that if AV detects some system tendency to fail (in the near future) or if a system has failed and is replaced by a back-up system, but needs to be repaired or maintained, AV should be designed in such a way as to send a request to the nearest service center to which it can arrive driving safely, otherwise it shall automatically call the towing service that would take it to the first service center or wait for a mobile expert trained repairman to repair it.

Based on all mentioned and the aspiration of manufacturers for AV to be always in (near-)perfect condition and that their operation will not be possible if some major system is down, the question of the need of AV periodical technical inspection arises. In our opinion, if AVs are able to control its components in some of all of aforementioned ways, a periodical technical inspection as a prevention will not be needed. On the other hand, this would require monitoring of all AV components, which means the installation of additional control systems that further increase the AV price, total mass, fuel consumption (due to increased mass), as well as fuel costs and environmental pollution. So, another proposal is to constantly monitor the AV key (critical) components which failure could lead to a road accident, and not critical components degrading slowly or with long lifecycle period should be tested on periodical technical inspection.

Barrier 3: Smart tachographs YES or NO?

The next question arising is whether the existence of a tachograph in AVs is really necessary, especially in the case of Level 5 automation. If it would be defined that the presence of the driver is not necessary in the AV, the main purpose of tachographs would be obsolete, since there would be no need to monitor the (inexistent) driver's working, driving, break and rest periods. On the other hand, if it would be defined that the driver must be in the AV, does it mean that it is necessary to change the legal basis since the driver would not be exposed to so much effort because he is not operating the vehicle constantly (Level 3 and 4), or at all (Level 5) and thus he doesn't have to take obligatory breaks after 4.5 h of continuous driving period. Is it necessary to define additional (framework) legal provisions such as the AETR agreement, which are only applicable when the driver is in the AV. Would this make additional complications in terms of monitoring and enforcing drivers (which is already quite complicated) since the driver can be engaged in operating non-automated vehicle during certain days, and operate AVs during others. It is also important to consider whether the transportation and logistics companies want to pay drivers "just to sit in the AV and do nothing". If they don't, the additional wages reduction due to reduction of work duties would represent a major issue demanding to be solved, since the drivers are already underpaid. So, it may be necessary to engage trained personnel (e.g. engineer) with specific expertise to remain in the vehicle, to monitor cargo distribution and securing, to intervene in cases of AV faults, failures, malfunctions and breakdowns. Also, the tachograph can assume a "black box" function in AVs, such as in airplanes. In this case, the tachograph, should record all the AV parameters in real-time and in case of traffic accident it can provide all relevant information regarding AV operation before the accident happened. This could help establish if the AV caused the accident or something else, anyhow the initial purpose of the tachograph as we know it would be changed.

4. CONCLUSION

The primary goal of this paper is to draw attention to possible barriers which would inevitably occur when AVs are implemented in the commercial transportation, specifically in freight transportation. The authors of this paper focused on the possible barriers that may arise during implementation of commercial AVs, and emphasize the need for further research in this field. The paper examines barriers such as axle load (especially overload), responsibility for the proper/inadequate cargo distribution and securing, cargo compartment security/access control, vehicle stability loss due to improperly distributed and/or secured cargo. Besides that, the AV maintenance problem and faults, failures, malfunctions and breakdowns were examined and what should be done in that situation, as well as the necessity to use the tachograph in observed vehicles and what should be done with existing international and national legal framework. Some of the responsibilities of the participants in the logistics chain regarding mentioned barriers were proposed. One of the future research directions is detailed consideration of the Incoterms rules and defining all obligations, responsibilities and expenses of participants' in the logistics chain where commercial AVs are engaged.

ACKNOWLEDGMENT

The paper is partially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia through project TR36010.

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CROWD LOGISTICS - A NEW CONCEPT IN REALIZATION OF LOGISTICS SERVICES

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Abstract: *Crowd logistics is based on the idea of a network of connected members that realize the transport of goods in order to improve the efficiency and sustainability of the physical movement of goods, as well as their storage, delivery and use around the world. Crowd logistics relies on individuals who are connected with mobile technologies and focus is on small operations. The essence of crowd logistics is to create a connection between people who have certain logistics resources and those with logistics needs. The aim is to minimize inefficient use of resources and use free capacities. In this paper the solutions applied in practice have been explored. Among other things, a detailed overview of different types has been given. In this research 73 active services were identified and divided in three new groups defined in this paper. An increase in the number of new services on an annual level of about 10% was observed.*

Keywords*: crowdsourcing, crowd logistics, delivery, network*

1. INTRODUCTION

During the past decade there have happened various changes in the ways that world functions, and significant part of that represent changes in the field of information technologies use. Nowadays, technologies are inevitable part of everyday life regardless of whether they are used by children, adults or elder.

One of the areas that IT (information technologies) has significant impact on is certainly logistics. Technologies such as: blockchain, robotics, 3D printing, augmented reality etc. have enabled progress in logistics operations that provide better efficiency and lower costs in entire supply chain. This is due to quicker respond to critical situations by providing intelligent solutions combining human knowledge and accuracy of IT. It is also possible to predict future situations and prepare for them using all the advantages of existing resources. Essential parts of every logistical system are transport and warehousing of goods on their way to the final user. These processes should be done in the way that will lead to maximization of final user's satisfaction, and it requires reliability and accuracy in their realization. IT solutions are what makes that possible if used appropriately. Possibilities are numerous and they lead to more frequent and smaller

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deliveries as well as proper use of available space, which are trends in the field of logistics. Crowdsourcing is one of the most important concept and involves crowd in realization of logistics activities.

Based on all of the above, it can be concluded that there is a great perspective on the development and application of this kind of service. This is also one of the main motives of this research. In this paper, the main focus of the research is identification and analysis of applied solutions in practice.

One of the possible solutions is crowdsourcing which is the subject of this paper. Essential characteristics of the concept are described in section 2, as well as types of crowdsourcing in section 3. There is also section 4 that deals with current situation in the world market through statistic analysis of crowdsourcing and shows the advantages of crowdsourcing through practical example of company that realizes processes using this concept.

2. PROBLEM DEFINITION

Crowdsourcing refers to involving ordinary people in the realization of logistics operations. It represents combination of two words: "crowd", meaning a mass of people, and "outsourcing", which describes the shift of certain processes and activities to third parties (Odongo, 2017). Implementation of crowdsourcing concept in logistics is recognized and defined as crowd logistics. This concept is based on network of connected people that use their spare time and/or space to help other people and earn money in return. That is enabled by using applications and platforms to find someone nearby that needs help or somebody that can do a service, depending on what one needs at the moment. Figure 1 illustrates how crowd logistics system works.

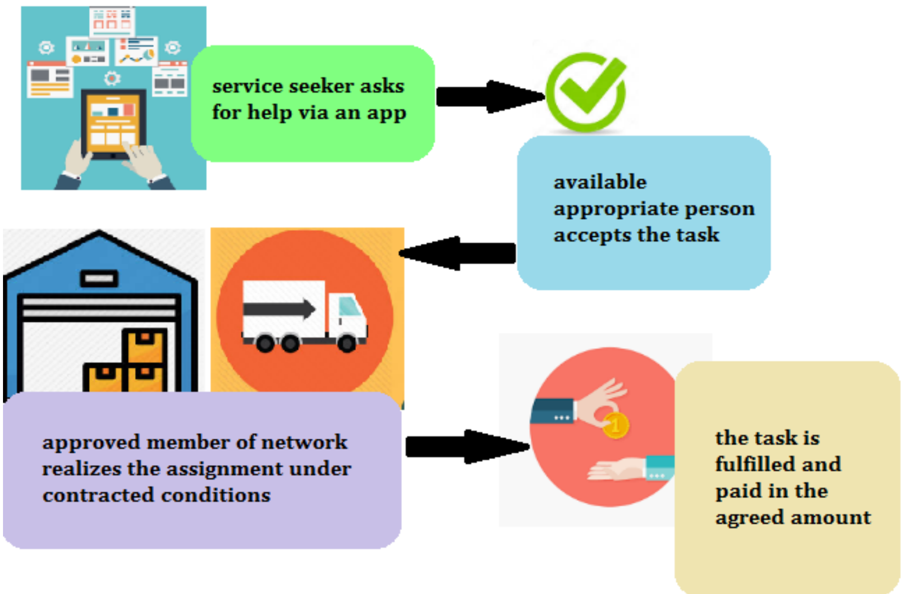

Figure 1. Crowdsourcing system

The most important part of crowdsourcing system are certainly people. The more effective network of connected people, the better and cheaper service and more satisfied clients are. That is possible only when there is an appropriate digital implementation that enables fast reaction to all needs through utilization of smart devices and applications that are available to every member of crow logistics network (Rouges & Montreuil, 2014).

It is important to point out that crowd logistics systems are based on the will of people, and that it is up to them to decide whether they will fulfill certain task or not. There is no employment contract that forces them to participate in crowd logistics processes, they can stop being part of network at any moment. However, companies use different methods to motivate people to join their platform by highlighting certain advantages: environmental benefits, social ties, altruistic experiences etc. (Carbone, 2017).

The most significant effects of this concept are reflected in lower costs of logistics operations and better usage of people's time and available space. The goal is to create a network of symbiotic relationships by matching logistics assets and capabilities with logistics needs (Carbone, 2017). Some people get the opportunity to access services and products in an easier and faster way, at a lower price, while others use empty space they own to earn extra money. It's a win-win situation that makes all the participants of crowdsourcing network satisfied and that is what makes people want to join such initiative.

Crowd logistics also has certain impact on the environment, which can be positive or negative, depending on some important factors: transport behaviour (empty kilometers, packages taking order etc.), consolidation of package, crowd's modal choice (bicycle, delivery on foot etc.). Since processes are being realized by crowd and not by professionals, there is no need for huge amount of assets, which is also good side of this concept. The essential part of crowd logistics is that it implies usage of unutilized space instead of requiring more of it. That can also be important for logistics companies that could reduce costs and achieve better efficiency by hiring crowd (Rai, 2018).

Aside from good effects of crowd logistics and crowdsourcing in general, there can also come to certain problems depending on reliability of the crowd. It is important that people are able to fulfill the assignment they signed up for and that includes access to all needed resources.

3. TYPES OF CROWD LOGISTICS

There are several ways to engage crowd to fulfill certain assignments in order to help other people. The existing literature shows different ways to divide types of crowdsourcing. Some authors only recognize ways of moving goods from point A to point B by crowd when they talk about crowdsourcing, while others consider renting storage places too. This paper shows all the types of crowd logistics that have been noticed through the conducted research. On the basis of various divisions in existing literature, a new division has been created in this paper which, in the best possible way, systematizes all existing ways to sort the types of crowd logistics.

3.1 Local delivery service

This type of crowdsourcing needs an access to certain transport resources and logistic abilities that will enable crowd to deliver package at the required time to the required place. These resources can be: cars, vans, scooters, bicycles etc. or the task can be fulfilled on foot, depending on the size of package and the distance of destination. Local delivery service is significant in big cities where the movement of large number of people is represented on daily basis. It offers fast and cheap delivery of different consumer goods, small packages and food from restaurants.

3.2 Crowdshipping

This type of crowdsourcing can be realized in two different ways. One way is to order goods from abroad at a lower price than in the country of residence or to order something that doesn't exist on the domestic market. That includes using certain platform to find a person that travels from country that product is from, to country one lives in. Other way is to find the driver of a particular vehicle with enough space and adequate characteristics for carrying certain package to pick it up from one location and move it to another that is on his route and can be in another country or even continent. Good side of this type of crowdsourcing is that both driver and service seeker are in win-win situation. Driver uses empty space in his vehicle and gets extra paid while service seeker gets his package at a lower price.

3.3 Crowd storage

In addition to transport services, storage services can also be crowdsourced. This type of crowdsourcing is realized by renting property resources of people, such as: basements, garages, rooms or yards. They can be reached via certain platforms for this kind of services, and as earlier described two types of crowdsourcing, this type also provides a win-win situation.

4. CURRENT SITUATION IN THE WORLD CROWDSOURCING MARKET

The main part of this paper consists of the conducted statistical research that illustrates current situation in the world crowdsourcing market. Tables 1,2 and 3 bellow consist of service providers that can currently be found, and some of their main characteristics.

The results presented represent a part of the conducted research, which included certain literature research: scientific papers, professional publications, websites of individual solutions. 73 companies were identified, of which 13 represent crowd storage group of solutions, 34 are from crowdshipping group, and there are 26 companies that provide local delivery service.

Figure 2 shows current situation in the world in terms of the development of crowd logistics. The concept is most prevalent in North America and Europe, primarily because on these continents there are countries that are the most developed when it comes to information technologies. Nevertheless, crowd logistics slowly expands on other parts of the world, bringing significant changes in the operations of different companies and the realization of logistics processes. Many companies have been developed and more of them appear every year. The subsections below are about those companies and their development through years.

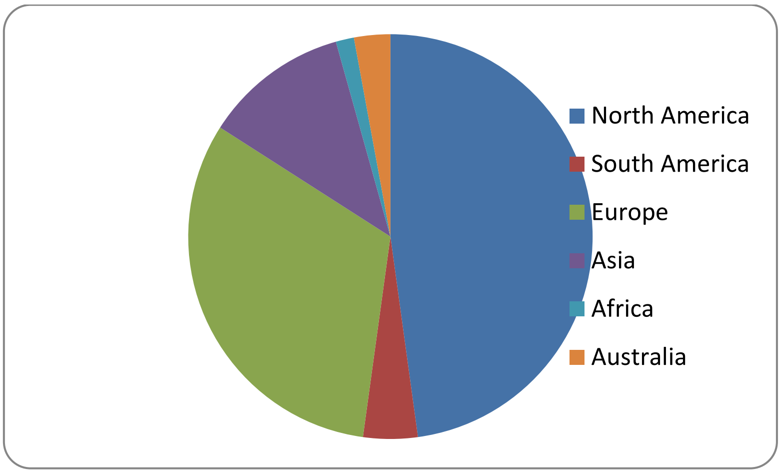

Figure 2. Development of crowd logistics in the world

4.1 Crowd storage solutions

Data from table 1 shows that crowd storage has evolved in the past decade, mostly in Europe. New service providers appear almost every year which shows that interest for this kind of services grows. Beside existing interest in crowd storage in Europe, it should be pointed out that in the past few years USA have also been developing this type of service. Other parts of the world haven't shown interest in crowd storage significantly yet.

Table 1. Crowd storage world market

Name	Founded	Founding place
MonsieurParking	2008	Paris, France
Costockage	2012	Paris, France
Storemates	2012	London, UK
Storenextdoor	2012	Bath, UK
Jestocke	2013	Paris, France
Spacer	2015	Pyrmont, Australia
Stasher	2015	London, UK
Stashbee	2016	London, UK
StoreAtMyHouse	2016	Los Angeles, CA,USA
Djeepo	2016	Amsterdam, The Netherlands
YesWeStock	2016	London, UK
Neighbor	2017	Lehi, Utah, USA
HopperStock	2017	Cleveland, Ohio, USA

4.2 Crowdshipping solutions

When it comes to crowdshipping situation is different. This type of crowdsourcing exists much longer than crowd storage and it's represented in many different parts of the world. Therefore it's easy to conclude that there are many more providers of this kind of service. Table 2 shows the most significant crowdshipping providers in the world market.

Table 2. Crowdshipping world market

Name	Founded	Founding place	Name	Founded	Founding place
uShip	2003	USA	Entrusters	2014	USA
Shiply	2008	UK	GOShare	2014	USA
Nimber	2010	Switzerland	Jwebi	2014	France
Bellhops	2011	USA	ShipBob	2014	USA
Bistip	2011	Indonesia	Parcl	2014	Australia
PiggyBee	2012	Belgium	Airmule	2015	USA
PleaseBringMe	2012	USA	BuddyExpress	2015	USA
TruckPad	2012	Brazil	Grabr	2015	USA
Worldcraze	2012	France	Point Pickup	2015	USA
Backapackbang	2013	USA	Qempo	2015	Peru
Cargomatic	2013	USA	BeckFriends	2016	India
Colis-Voiturage	2013	France	MyBoxMan	2016	France
GoGoVan	2013	Hong Kong	Ouibring	2016	Singapore
Manyship	2013	USA	AirWayBill	2017	Spain
Schelp	2013	USA	Outvio	2017	Spain
Sontra	2013	Brazil	Friendlivery	2018	France
Zaagel	2013	Egypt	Pigeon Express	2018	Belgium

Unlike crowd storage, crowdshipping is equally developed both in Europe and USA. They are leaders in crowdshipping world market, but this concept is also in progress in Asia, South America, Africa and Australia. It can be expected that development of crowdshipping will continue in all parts of the world because all the good sides of it are attracting more and more people to become part of such network.

4.3 Local delivery service solutions

Finally, local delivery service represents the most developed type of crowdsourcing, comparing to other two types. This kind of network spreads rapidly, mostly in large cities because of its advantages which were described earlier in this paper. Table 3 contains the most developed providers of local delivery service in the world.

Data in table 3 shows that nearly 60% of local delivery service contains of delivering food. A lot of crowdsourcing companies have contracts with different restaurants, so people can order food at any time. They can choose desired restaurant via an application so the first available appropriate person on network can realize the delivery at short time. The same applies to other types of packages that need to be delivered.

Table 3. Local delivery service

Name	Founded	Founding place	Current availability	Type of goods
Grubhub	2004	Chicago, IL, USA	1700+ cities in USA	food
Ele.me	2008	Bejing, China	2000+ China cities	food
Zomato	2008	Gurugram, Haryana, India	worldwide	food
OrderUp	2009	Baltimore, MD, USA	60+ cities in USA	food
Delivery Hero	2011	Berlin, Germany	worldwide	food
Postmates	2011	San Francisco, CA, USA	2900+ cities in USA, Mexico City in Mexico	different types of goods
Seamless	2011	New York City, NY, USA	USA	food
Caviar	2012	San Francisco, CA, USA	12 USA cities	food
Foodpanda	2012	Berlin, Germany	worldwide	food
Instacart	2012	San Francisco, CA, USA	USA and Canada	different types of goods
BuddyTruk	2013	Santa Monica, CA, USA	4 USA cities	furniture
Deliv	2013	Menlo Park, CA, USA	35 USA cities	different types of goods
Deliveroo	2013	London, UK	200 European cities	food
Dolly	2013	Seattle,WA, USA	5 USA cities	furniture
DoorDash	2013	Palo Alto, CA, USA	600+ USA cities	food
Favor Delivery	2013	Austin, TX	50+ cities in TX, USA	different types of goods
GoPuff	2013	Philadelphia, PN, USA	50+ USA cities	different types of goods
Kanga	2013	Atlanta, GA, USA	USA	different types of goods
LaLaMove	2013	Hong Kong	9 Asian countries	different types of goods
Saucey	2013	Chicago, IL, USA	5 USA cities	alcohol
Eaze	2014	San Francisco, CA, USA	100+ cities in CA, USA	medical cannabis
Lugg	2014	San Francisco, CA, USA	9 USA cities	furniture
Swiggy	2014	Bangalore, India	60 locations PAN India	food
Uber Eats	2014	San Francisco, CA, USA	worldwide	food
Dahmakan	2015	Kuala Lumpur, Malaysia	Kuala Lumpur, Bangkok	food
Wolt	2015	Helsinki, Finland	16 European countries	food

Another interesting fact is that all analysed providers have significantly made progress through years. Their business has spread to hundreds and thousands of cities, which only indicates that progress will continue. The US is definitely the leader when it comes to foundation of local delivery service providers with 65% participation, while other 35% were founded in Asia or Europe. It is also important to say that 15% of analysed providers do business worldwide, which can be seen in the table 3.

4.4 Comparative analysis of crowd logistics types

The conclusion is that crowd storage is the least developed type of crowdsourcing, while crowdshipping and local delivery service are developed worldwide. The graph below shows that crowd storage is the youngest and least developed type of crowd logistics. This indicates that the focus is on transport, and that it is easier to find a vehicle with extra space than a free storage space. It can also be seen that the most providers have been formed in the field of crowdshipping. The largest number of these providers had appeared between 2013 and 2015 - 55%, which means that crowdshipping experienced an expansion at that time. After that, although in smaller numbers, new companies have appeared every year in different parts of the world, which indicates that the concept has attracted a lot of people's attention and that in the future, it will only develop more and more.

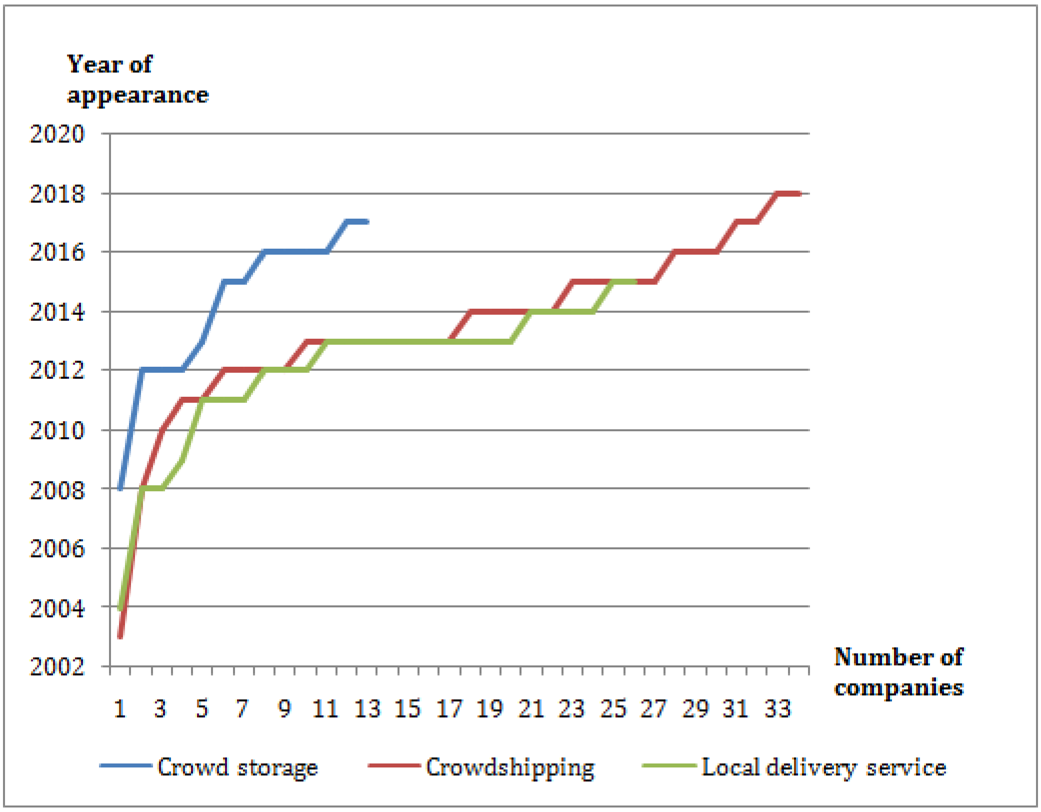

Figure 3. Development of types of crowd logistics through years

On the other hand, although there is a smaller number of local delivery service providers, it does not mean that this type of crowd logistics is less developed. On the contrary, the existing companies have developed and expanded to other cities for years, some of which have been developed in several thousand cities and in different countries too. The fact that there has not appeared a new significant company in recent years indicates only that already existing companies have strengthened and taken over the market. The largest number of providers came into existence in 2013, which, according to previous data on crowdshipping, indicates that crowd logistics was at the height of its development that year, in terms of the emergence of new companies.

Moreover, local delivery service requires a lot of people involved so the network would work because of frequency of processes, and it can be said that this is the most important and the most useful type of crowd logistics. That is because cities are getting bigger and more populated so the processes inside them are becoming more complex and harder to realize. Therefore, one well organized crowd logistics network could be acceptable local delivery service solution in cities.

4.5 WOLT - Local delivery service provider

Since it was concluded that local delivery service is very significant type of crowdsourcing, one provider from this area was chosen to be described, so reader would have wider picture about the concept itself. The chosen provider is Wolt and it operates in many cities and countries in Europe.

Wolt provides online ordering and delivery of food via mobile application. It started operations in 2015. and has since expanded into 15 countries across Europe. It will also soon begin operations in Belgrade. The company is partner with over 2,000 restaurants and allows each restaurant to subscribe to the network and receive the customer's order, paying for the delivery through crowdsourcing and automatic credit card payment. The user chooses a restaurant via the Wolt application and makes an order, after which is notified when it will be ready for delivery.

The order is made by first choosing the appropriate restaurant and the desired meal through the Wolt application. After the selection has been made, the order is confirmed, where it is possible to see in what time the delivery will take place. An additional advantage is that the user can monitor the delivery through the application. Figure 4 shows how Wolt application works.

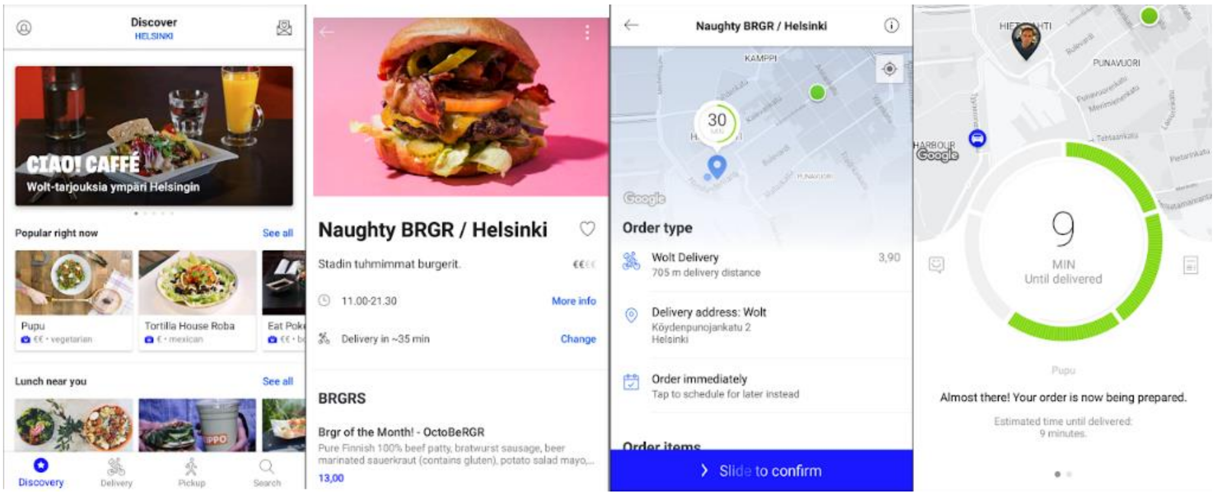

Figure 4. Wolt application (https://wolt.com)

In the background, the Wolt system paves the order with the available service provider. The driver takes over the order from the restaurant and delivers it to the user. It can be done on a bicycle, scooter, motor, car or on foot in some cases. According to Wolt's website, the company provides the following to the crowd: flexible working hours, payment for each completed delivery, a guarantee for a fixed schedule when the service provider prepares the working hours in advance, payments twice a month, weekly bonuses, work with the best restaurants in the city, part-time work.

5. CONCLUSION

Based on the topic that was discussed, it can be concluded that the concept of crowdsourcing has very positive effects, both on the business of companies and society at large. More efficient implementation of business processes is possible, as well as significant cost reduction through the minimization of necessary resources by engaging ordinary people. In this way, a winning situation for all members of the network is achieved, because the processes are done for everyone's benefit. Companies use less of their resources and are given a simpler organization, people get paid for a job they do at their discretion, users meet the requirements within the appropriate time limit, and the environment suffers less crowds and complications in traffic.

When it comes to Serbia, crowd logistics slowly evolves, which is shown in the practical example that was described in this paper. A large number of experts in the IT sector, as well as logistics market that is not negligible, contribute to the possibility that this concept will further develop and change the way of doing business in Serbia and its surroundings.

Crowd logistics is based on strong IT support that is constantly evolving, with new opportunities being constantly under consideration. In the future, it is certainly necessary to deal with these opportunities, as well as to extend this concept to different companies and activities, in order to optimize all processes that involve the movement of people and goods.

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Part III

INTERMODAL TRANSPORT AND LOGISTICS TERMINALS

INITIATIVES AND ACTIVITIES FOR THE DEVELOPMENT OF INTERMODAL FREIGHT TRANSPORT IN SLOVENIA

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Abstract: *European Union (EU) has a strong focus on developing intermodal transport as a solution to slow down the growth of unimodal road freight transport. Different strategies and approaches have been undertaken by the EU, where the modernization of railway infrastructure and service standardization step out. At the same time, also the national governments have a significant role in promoting and encouraging the use of intermodal transport.*

In this paper, the authors provide an overview of intermodal transport development in Slovenia. They assess different national measures and programmes that can be applied, in order to support the intermodal transport, and investigate the application of these measures. To conclude, they create a list of suggestions on future activities for promotion of intermodal transport in Slovenia, in order to support EU and primarily central European region's expectations for the use of southern maritime European transport route and the two core network corridors.

Keywords: *intermodal freight transport, intermodal corridors, intermodal connectivity, EU initiatives, national measures*

1. INTRODUCTION

Freight transport presents an important element in the development of the economy and the society, but the growth of freight flows is becoming challenging. The overall demand for freight transport in Europe is constantly growing; based on the available data from the total intra-European (EU 28) freight flows increased by 12.8% in the period from 2000 to 2016. This is less than the growth of gross domestic products (GDP) at 2005 prices was in the same period (around 20.8% in total), which is good; however, it is not good that the freight flows are increasing much faster on roads than in any other transport mode, resulting in a growing share of road freight transport in modal split. In fact, the share of freight flows (in terms of ton-kilometres) done on roads increased from 46.5% in 2000 to 49.3% in 2016 49.3%, while the rails lost 1.3% in share to drop to modest 11.2% (European Commission, 2018). The existence of empty rides of road freight vehicles

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makes these numbers even worse; around 20% of trucks run empty and partially loaded vehicles are also very common (Transport & Environment, 2017).

The main goal of the EU transport policy is to achieve an economically efficient transport that is at the same time safe and green. One of the solutions to reach this goal is by enhancing the use of intermodal transport where rail, inland waterways or sea are used for long-distance transport while first and last mile delivery are done by road transport, in order to provide flexibility in door-delivery services. Intermodal transport, either accompanied (road vehicles) or unaccompanied (semi-trailers, containers and swap bodies) can provide several benefits, like for example lower transport costs, shorter transit times (not always achievable), reduced consumption of fossil fuels and last but not less it can remove freight vehicles from roads.

In this paper the authors present an overview of intermodal transport development in Slovenia with the assessment of different national measures and programmes that can be applied to support the intermodal transport, and investigate the application of these measures in Slovenia. They create a list of suggestions on future activities for promotion of intermodal transport in Slovenia, in order to support more intensified use of the southern maritime European transport route.

2. INTERMODAL TRANSPORT IN EU AND SLOVENIA

The beginnings of intermodal transport in Europe date back to the late 1960s when some European railways had a vision of developing combined road-rail freight transport of unified loads, where the rail should have the priority on longer transport routes and the road transport should be used just on shortest possible distances (Seidelmann, 2010; Bektas & Crainic, 2007).

The intermodal rail transport is gaining importance in EU. In the period from 1992 when Directive on combined transport was written to 2014 when the external study on the achievements of combined transport was done, a 2.5 trillion tonne-kilometres were shifted from roads, and intermodal transport achieved savings of 2.1 billion EUR in 2011 alone (EC, 2016). According to Report on combined transport (UIC, 2019), 253.4 million tons of cargo were transported in accompanied or unaccompanied intermodal rail transport in 2017, almost 10% more than in 2015. The share of intermodal rail freight in total rail freight is now around 22%, but it is having a growing trend.

Intermodal rail freight transport has been in use in Slovenia since 1974, with the first “piggy-back" trains connecting Ljubljana with Köln and Munich. In 1989 established company YuCombi, later renamed into Adria kombi ltd., has a wide spread network of trains transporting containers, semi-trailers and swap bodies to 72 terminals in Europe and currently offers nine specialized services both in domestic and in international traffic. In addition, they also provide tailored services for automobile industry and for fast moving consumer goods.

In 2017, around 5 million tons of cargo were transported in combined transport in Slovenia (SŽ, 2018), mainly sourcing or sinking in the Port of Koper, the only Slovenian international cargo port. The Table 1 shows main origins and destinations for combined transport in Slovenia.

Table 1. International combined transport from and to Slovenia in 2016

	From Slovenia (1,000 TEU)	To Slovenia (1,000 TEU)	From Slovenia (1,000 t)	To Slovenia (1,000 t)
Austria	8.09	49.55	78.89	675.84
Belgium		1.00		11.20
Bosnia and Herzegovina	0.01	0.01	0.11	0.01
Croatia	0.63	0.86	4.72	5.99
Czech r.	25.52	25.96	181.10	228.08
Finland		0.03		0.28
Germany	10.64	15.17	44.32	258.83
Greece		0.10		0.20
Hungary	64.12	115.10	643.28	954.16
Italy	2.84		4.32	
Luxembourg	0.01		0.07	
Macedonia	0.03		0.09	
Netherlands		1.86		23.27
Norway	0.02		0.08	
Serbia	0.19	0.21	1.88	0.36
Slovak r.	65.44	193.48	446.93	1,440.44
Sweden		1.15		11.49
Total	**177.5**	**404.48**	**1,405.79**	**3,610.15**

Source: (UIC, 2017)

There are three combined transport providers in Slovenia, besides Adria Kombi, also Kombiverkehr and Ökombi; however, Adria Kombi remains major provider of combined transport services in Slovenia. The growth of their major services in the period from 2001 to 2017 is impressive; the importance of accompanied traffic has declined since 2009 and the amount of units transported was actually 6% lower in 2017 than it was in 2001, but other services, namely un-accompanied and domestic intermodal transport have increased by 854 and 764%, to reach almost 170,000 and 50,000 transported TEUs respectively.

3. POLICY SUPPORT FOR INTERMODAL TRANSPORT IN EU AND SLOVENIA

The objective of European transport policy is to develop basis for optimal combination of transport services into one single product that uses efficient and cost-effective integrated transport and where competition between transport operators remains open (CEC, 1997). The European goal is also to shift 30% of road freight on longer distances (over 300 km) to alternative transport modes by 2030, and more than 50% by 2050 (EC, 2011).

The solution that stands out, but has not yet been exploited in its full potential, is the intermodal transport.

Intermodal or combined transport was first systematically addressed by the Directive 75/130/EEC of February 1975. This Directive established of common rules for certain types of combined road/rail carriage of goods between Member States and was later on several times amended. In 1992 it was recast into the Directive 92/106/EEC. Its latest amendments have been considered in July 2018.

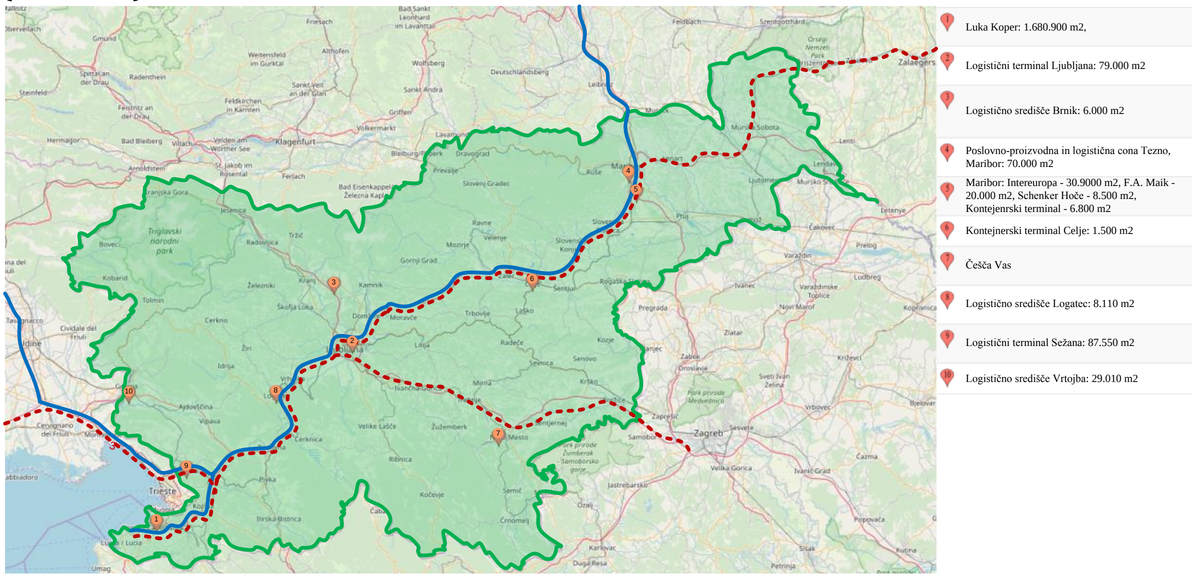
Intremodal transport requires support on European level in terms of adequate transport infrastructure which is supported by compatible technologies and unified procedures. And intermodal transport is getting it in the form of Trans European Transport Network (TEN-T) and the European Rail Traffic Management system (ERTMS) which, once deployed (it has to be fully deployed on core network by 2030), will increase the capacity of existing lines by allowing higher speeds and assuring lower production, operational as well as maintenance costs and enhancing cross-border interoperability. In this way the rail sector will become more reliable and competitive.

Since 2001 four railways packages have been adopted with the goal to make the rail system liberalized and non-discriminatory for non-national rail operators as well as more competitive in regards to other transport modes. The last one, the Fourth Railway Package which was adopted in 2016 consists of four core aims, including cutting administrative costs for railway operators and simplifying market entry while strengthening the role of infrastructure managers and opening domestic passenger market. The package is divided into two pillars, technical and market pillar. Within technical pillar, two directives, namely Directive 2008/57/EC on interoperability of rail system and Directive 2004/49/EC on railway safety, have been recast to Directive (EU) 2016/797 and Directive (EU) 2016/798 respectively. Member states need to transpose both directives into national law by 16th of June 2019, with an option to request an extension of up to a year. Also some other directives that do not directly affect the rail or intermodal transport, but can have indirect impact, like for example Directive 96/53/EC regarding weights and dimensions of commercial road vehicles or Eurovignette Directive, have been refreshed. And last but for sure not least, the long-time discussed internalisation of external costs of transport as well as fair and efficient pricing, once arranged, would give significant wind in the back to expanded use of combined transport.

Intermodal transport must be promoted through the policies at all political levels (Macharis, 2011), including national, so some Member states established active policies to promote intermodal transport (Pedersen, 2009). In some Member states restrictions for heavy good vehicles exists over the weekends, some increase the fuel price or the toll prices, while others provide national funding measures and programmes for combined transport. These measures include funding of combined transport operations, the infrastructure, the suprastructure and equipment, research and fiscal support (summarized from UIC, 2019).

Slovenia has signed several agreements related to the intermodal transport, for example European Agreement on important international combined transport lines and related installations (AGTC Agreement) from 2005, the Alpine convention which is an international treaty between the Alpine countries as well as the EU, for the sustainable development and protection of the Alps, or the Convention concerning International Carriage by Rail (COTIF).

Two TEN-T corridors (Baltic Adriatic and Mediterranean corridor), and four rail freight corridors (RFC) corridors (RFC 5 – Baltic Adriatic, RFC 6 – Mediterranean, RFC 10 – Alpine-Western Balkan and RFC 11-Amber corridor) cross Slovenia. In addition, ten locations in Slovenia offer multiple logistic terminals and storage facilities (Figure 1); five of them are important for combined sea-road-rail transport. Those are the port of Koper (sea-road, sea-rail), Ljubljana (road-rail), Celje (road-rail), Maribor (road-rail) and Sežana (road-rail).



Source: based on (Zanne, Krmac, Bajec, & Škerlič, 2019)

Figure 1. TEN-T corridors and logistics terminals in Slovenia

The Slovenian transport policy from 2006 stated that intermodal transport will be supported through an appropriate fiscal policy. Nevertheless, there are no fiscal incentives for domestic haulage carriers involved in combined transport (Ur. l. RS 23/2018); however, there are some fiscal exemptions for carriers from non-EU countries if such carriers carry the cargo to or from the Port of Koper and do not perform any additional cargo manipulations in Slovenia or if they use the piggyback transport and road haulage only in feeder or final delivery carriage. This is in line with the Directive 92/106/EEC on combined transport.

The funds obtained from the annual duty for the use of road vehicles are no longer strictly aimed to the roads; in fact, from 2010 to June 2012, those funds were completely redirected to the railway infrastructure, and according to the last Act on the provision of funds for investment in transport infrastructure, these funds, together with the funds from the concession fee of Luka Koper, are put into common transport infrastructure budget.

Although European Commission generally does not support subsidies in transport, subsidies for rail infrastructure and rolling stock are possible. In Slovenia state compensation can be given to cover a part of the funds spent by combined transport operators for investments, research as well as for a part of the cost of transport, which represent special interest of the state (Ur. l. RS 108/2000).

The Order on road traffic restrictions in the Republic of Slovenia (Ur. l. RS 75/2011) banishes freight vehicles from the roads on Sundays and holidays from 8am to 9pm and during the tourist season on Saturdays from 8am to 1pm; touristic season lasts from the last weekend in June until the first weekend in September. This limitation is not in applicable to the vehicles carrying perishable goods but also for vehicles that are used in combined transport.

Road freight vehicles which are employed in combined transport, are permitted to have maximum authorised mass of 44 tons but only on the route towards the nearest railway terminal or port, while all other road freight vehicles are limited to a maximum weight of 40 tons (Ur. l. RS 4/2001). In addition, the Rules on restricted use of national roads for the transport of heavy goods vehicles with a maximum authorised mass exceeding 7.5 tons (Ur. l. RS 102/2006) require the use of the higher-level state roads when existing parallel to roads passing through the settlements for the heavy freight vehicles.

Slovenian tolling system for vehicles with maximum authorised mass of more than 3.5 tons is differentiated by vehicle type (number of axes), Euro emission standard and distance travelled. The electronic tolling system, which was set up in April 2018 prevents skipping the toll payment, which was earlier very present by road freight vehicles.

In addition, starting from January the 1st 2019 and lasting until the end of 2052, the additional charge in form of 15% of the weighted average of infrastructure fee, is used on Primorska section of A1 motorway, while on Štajerska section an extra 5% is applied as can be seen from Table 2. In percentage change this actually means that cleaner vehicles are penalized more than older and dirtier ones. The collected money will be directed into the funds for railways infrastructure construction, more precisely

Table 2. Differentiated toll rates (VAT excluded) on Slovenian motorways

R4			
	A1 – Primorska section	A1 – Štajerska section	Other motorways
EURO VI	0.30034	0.26482	0.25699
EURO EEV	0.30034	0.26482	0.25699
EURO V	0.34314	0.30758	0.29991
EURO IV	0.38593	0.35046	0.34274
EURO 0, I, II, III	0.47163	0.43610	0.42832
R3			
	A1 – Primorska section	A1 – Štajerska section	Other motorways
EURO VI	0.14778	0.12789	0.12357
EURO EEV	0.14778	0.12789	0.12357
EURO V	0.16828	0.14845	0.14413
EURO IV	0.18890	0.16910	0.16478
EURO 0, I, II, III	0.23013	0.21032	0.20592

Note: Prices per kilometre are calculated in reverse from the total price for different routes attained from https://www.darsgo.si/portal/si/izracun

Source: (Zanne, Krmac, Bajec, & Škerlič, 2019)

4. DISCUSSION

Slovenia has important geo-strategic position in Europe and this is proved by planned infrastructures that are or will be crossing the country. The role of Slovenia will be further emphasized if the Blue banana, originally stretching from Manchester to Milan, continues to move towards eastern part of Europe. In this case the role of the southern maritime European transport route, which provides the shortest and most efficient connection from the East towards the Central European countries through the ports of North Adriatic, will gain even more importance. This will potentially generate extensive extra freight flows to the already increasing flows which are currently still mainly accommodated by the roads.

The TEN-T and RFC corridors are to be set as the only feasible and safe solution for such a growing traffic flows. Slovenia has postponed most of its investments (more than 60%) into TEN-T priority projects (they mostly coincide with the corridors) to post-2020 period (TENTec, 2018). These investments are into rail infrastructure, as the road infrastructure on corridor directions already completely complies to TEN-T requirements. With such an approach, Slovenia is in delay in respect to other countries and risks to not having enough done by 2023 when the next detailed examination is scheduled.

5. CONCLUSIONS

In the market economy, price is generally the dominant criteria when it comes to selection of the product and so it is also with the selection of transport mode. However, the market prices in transport still do not reflect all the costs incurred, therefore the decisions on transport mode are not socially completely satisfactory and the rail or combined rail-road transport is not competitive to unimodal road transport in terms of price, and often also in terms of time required to cover the distance.

European freight transport is still mostly road based and oil dependant, which is not in line with the transport policy goals nor Paris Agreement. Regardless of the growing volume of combined transport, it is still not contributing enough to the modal shift. Its further establishment requires harmonized activities around EU to construct interoperable infrastructure as well reliable information systems and feasible frame for fair and efficient pricing in transport. This is the precondition for expansion of rail and intermodal transport, but also activities in each Member State are needed to support intermodal transport operators.

Majority of activities that can support intermodal transport in Slovenia are indirect; mainly in some way affecting and penalizing the road operators. Probably because current rail infrastructure, on which passenger trains have the advantage over cargo trains, cannot accommodate additional traffic.

Slovenia has to concentrate on fulfilling the TEN-T requirements on rail corridors that cross the country otherwise; it could lose the different EU funding possibilities or even the freight flows that bring the money to the national economy. This is the only viable long-term solution; however, it is expensive and time demanding. All interventions in rail infrastructure increase the network capacity; but the authors will focus on the traffic flow structure on Slovenian railways. They will investigate rail passenger traffic in Slovenia and estimate the potential shift of freight flows from roads to rails if certain rail capacities are freed up by cancelling out the least utilised passenger trains.

ACKNOWLEDGMENT

The research was carried out as part of bilateral project "The development of intermodal transport, intermodal nodes and hinterland network in the eastern Adriatic region" between Slovenia and Montenegro.

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LOGISTICS CHARACTERISTICS OF GOODS AND CONTAINERIZATION LEVEL

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Abstract: *The phenomenon of containerization is a well-researched theme. However, these researches are mainly in the context of new technical and technological issues and challenges, necessary for realization of such an transport technology, as well as dynamics of containerization and contemporary business models. The investigation of cargo being carried by containers appears to be underrepresented, which can be result of thinking that container represent the transport unit (box) that replaces a large number of smaller packages so it is primarily intended for general cargo. Containers could be used for transport of a large number of different types of goods, and types of packages, whether the level of containerization of particular goods depends on several factors. This paper aims at analyzing these factors in containerized level. It also looks at developing of special diagram showing the compatibility between the particular freight and container types. This paper will demonstrate how this diagram could be used on simple way in finding which types of container is suitable for specific types of commodity.*

Keywords: *commodity, freight density, containerization, diagram.*

1. INTRODUCTION

The containerization was the major change in 20th century transportation technology which has a decisive impact on the world economy. That is, there is a significant correlation between the enormous increase in the world trade and commodity flows, on the one hand, and the development of container transport on the other hand. Therefore it could be said that containerization was a catalyst for development of the world trade and economy in general. Similar statements could be found in a vast literature on transportation economics, such as Bernhofen et al. (2016), which emphasized the containerization as a logistics innovation responsible for the acceleration of the globalization of the world economy since the 1960s; or Levinson (2006) who noted that containerization had an outstanding impact on production and distribution for 50 years; and finally Rodrigue (2012) who pointed out that containerization has been a major

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driving force behind globalization. From a transportation technology perspective, containerization is based on the use of containers as loading or transport unit which could be transported by different transport modes and which enable fast, safe and easy transshipment of goods between them without any direct contact with the goods themselves. In such way, eliminating sometimes a dozen direct handling of goods, the containers enabled a direct technological connection between the producers and customers, while reducing the total transportation costs (Bernhofen et al., 2016). On the other side, containerization required a major technological changes in transportation and handling activities and facilities. These changes started in maritime transportation first (new form of ships, ports, and handling equipment) and progressed to engulf inland parts of the transportation chains, like rail and road transportation. Container shipping developed rapidly due to the adoption of standard container sizes in the mid-1960s and the awareness of industry stakeholders about the advantages and cost savings (Rodrigue and Notteboom, 2014). All these technological and economic aspects of the phenomenon of containerization are well-researched in literature. However, the investigation of cargo being carried by containers appears to be underrepresented, as Rodrigue and Notteboom (2014) has already stated. This could be result of perception of the container as a transport unit (box) that replaces a large number of smaller packages, which makes him primarily intended for conventional general cargo. However, such perception of the container must be expanded to consider the container as a transport unit that could be used for a large number of different types of goods, and types of packages, whether the level of containerization of particular goods depends on their logistics and market characteristics. This paper aims at analyzing the level of containerization regards extraction of the new market opportunities. It also looks at developing of special diagram showing the compatibility between the particular freight and container types. This paper will demonstrate how this diagram could be used on simple way in finding which types of container is suitable for specific types of commodity.

2. CONTAINERIZATION

Containerization represent a system of freight transport using standard shipping containers to unitize cargo, and which could be loaded and sealed intact onto ships, trains, planes or trucks. Container logistics thus incorporates transportation, packaging, handling, storage, and security together with visibility of container and its content into a logistic chain from source to user (Bhattbhatt and Verma, 2012). There are various container types (dry cargo containers, refrigerated, open top, open side, platform, insulated, tank and silo containers, etc.) aims for caring different types of goods (general cargo in boxes, cartons, pallets, bales; bulk, heavy machinery, semi-finished goods, perishable and fresh goods, bulk liquids, grain, bulk chemicals, livestock, etc.). According to Bernhofen et al. (2016) container adoption in international trade which occurred between 1966 and 1983 was accounts for dramatic growth in world trade (Figure 1). The growing importance of containerized trade is still evident through the increasing number of containers (of all sizes) in export/import freight flows, which is in case of US almost doubled between 2000 and 2007 (www.evisionfreight.com). After the weak performances of 2008/2009, containerized trade has continued to increase in the following years. In 2017 containerized trade accounted for 17.1% of total seaborne trade with an increase of 6.4% in comparison with the year before, which represents the fastest rate since 2011 (Review of Maritime Transport, 2018).

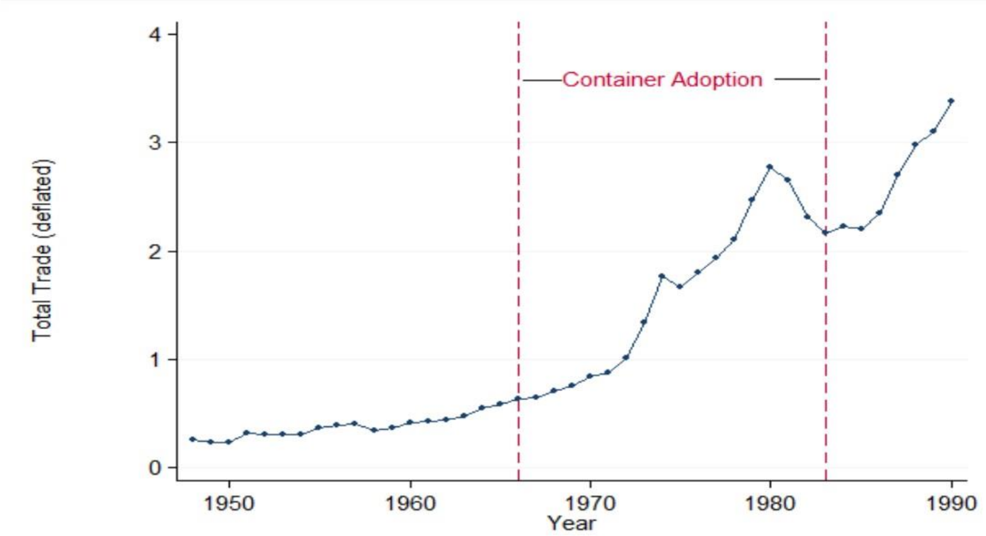

Figure 1. The growth of world trade: 1948-1990 (Bernhofen et al., 2016)

2.1 Waves of containerization

According to Guerrero and Rodrigue (2014) there are five waves of containerization (each of them lasts about 8-10 years), from container port traffic point of view, where each wave is represented by specific temporal growth pattern of containerization. The first wave of containerization was started in the late 1950s by shipping 58 Malcom McLean's 35 foot containers (actually aluminum truck bodies) and last till mid-1970s and re-opening of the Suez Canal. During this first phase, container's dimension was standardized by International Organization for Standardization (ISO) in the forms of 10, 20, 30 and 40 foot length, with a width of 8 foot and a height of 8.5 foot. Two dominant types of containers are 20 and 40 footers (ft), where standard ISO 20ft shipping containers with dimensions 6.06m (length) x 2.44m (width) x 2.6m (height) has a capacity of 33.1m^3, while ISO 40ft containers with 12.12m length have twice the capacity of 20ft containers. ISO 20ft container can each load around 22 to 26 tons while a ISO 40ft container, because of structural integrity issues, has a loading capacity of about 27 do 30 tons. Hence, 40 footers have only 15% more load capacity even the shipping volume is doubled in comparison to 20 footers. Cost effects of the five year's adoption of such standardized sizes of containers (from 1965 till 1971) are provided by Bernhofen et al. (2016). According to them productivity of dock labor had increased from 1.7 tons per hour (in pre-container era-1965) to 30 tons per hours (in 1971), while insurance costs has decreased from 0.24£ per ton to 0.04£ per ton, as well as capital locked up as inventory in transit from 2£ per ton to 1£ per ton.

The second wave represents an expansion of containerization in the period from the mid-1970s till beginning of 1980s. In this period several ports had increased their container throughout and became world's leading container ports (till the 2000s and the appearance of large Chinese container ports). This phase was characterized by global diffusion of containerization achieved mainly by entering the containers into the break bulk trades. This containerization's phase was with greater speed and size in comparison to the first wave, but still being costly to operate in some broad sense. The third wave concerns the largest number of ports and captures the massive diffusion of containerization (Guerrero and Rodrigue, 2014). During that period (mid-1980s till mid-

1990s), containerization had become a routine for not only manufacturers but also distributors and retailers. Technological advancements influenced the types of the container carrying ships: container/bulk carriers, container/ro-ro, and fully cellular containerships (Nurosidah, 2017). Containerization in this phase assumed improving of ship's productivity (less time-consuming container handling) and reducing of total transportation costs. According to Guerrero and Rodrigue (2014) this wave is statistically the most distinctive and assumes an acceleration of containerization, probably because of full internationalization in world trade which has stepped into the scene based on the entry of China and other countries from the Far East in the global sphere of production (Notteboom and Rodrigue, 2009).

In the fourth wave, from the mid-1990s till mid-2000s, the container became the standard mean for global freight distribution (Guerrero and Rodrigue, 2014) changing the economic geography (the massive entry of Chinese ports in global distribution networks), as well as changing delivery handling from labor-intensive to a capital and time-intensive operation (Nurosidah, 2017). The fifth wave concerns a massive phase of globalization and the usage of containerization to support the wide range of commodity chains. The last phase of containerization results in a significant increase in the volume of goods transported in this form. The containerization growth trend is still constant, except world economic crisis in 2008-2009, so that no one can define for sure the final stage of containerization diffusion or its maturity. As Notteboom and Rodrigue (2009) stated the future containerization will be largely determined by interactions within and between four inter-related layers: locational, infrastructural, transport and logistical, where the last one represents the most fundamental. The mix of logistics factors related to containerized goods will determine the future development of the global container transport system (Notteboom and Rodrigue, 2009). One of those factors is logistics characteristics of goods which will have an impact on decision regards identifying and setting of niche markets in future containerization.

2.2 Level of containerization

Containerization has developed from the specialization to generalization in terms of transported commodities (Yang et al., 2016). That is, all type of goods, such as final manufactured goods, processed food, produce, livestock, intermediate goods, processed materials, and raw materials, which could be packed in different type of packages, such as boxes, bags, drums, pallets, bales, rolls, etc. could be transformed into the form of unitized cargo such as containers. The degree of containerization for particular types of goods, or group of types is different. Some goods are almost fully containerized (such as coffee and bananas), while for others containerization is still at its beginning (such as lumber and grain). Level of containerization for particular type of goods mainly depends on their market characteristics (value-weight ratio) and logistics characteristics (based on size and frequency of shipments, density, packaging, and perishability). According to Yang et al. (2016) containerization is traditionally mainly applied for high-value manufactured commodities, such as electronic device, furniture, toys, apparel, sports equipment, works of art, etc. An example of high value commodity where 95% of their imports into Europe are containerized is coffee (Rodrigue and Notteboom, 2014). The top containerized commodities imported to the US in 2004 are from the groups: "machinery, boilers, reactors, parts"; "electric machinery, sound and television equipment, parts"; and "vehicle and parts", with total value of imported goods of 38; 31.7; and 12.1 billion of USD respectively (www.evisionfreight.com). As Karamperidis (2013) has stated, some rough calculation of the average value of contents of the global seaborne container equals 42,000 USD per TEU (Twenty-foot Equivalent Unit). Taking into account the fact that container could be shipped, for example from the Far East to Europe for 1,000 USD it means that the average freight rate equates to 2.38 percent of the value of the container contents. On the other side, the majority of low-volume products like grain, iron ore, coal, and other raw materials are basically transported via bulk shipment. However, many of those segments are in the process of being containerized.

In accordance with the previously stated facts, it could be said that containerization is commodity dependent, which results in a wide variety of existing and potential containerization levels, as it's already noted by Rodrigue (2017). The same author further stated that even within the same groups of commodity (defined by Standard International Trade Classification-SITC†), levels of containerization differ (Figure 2).

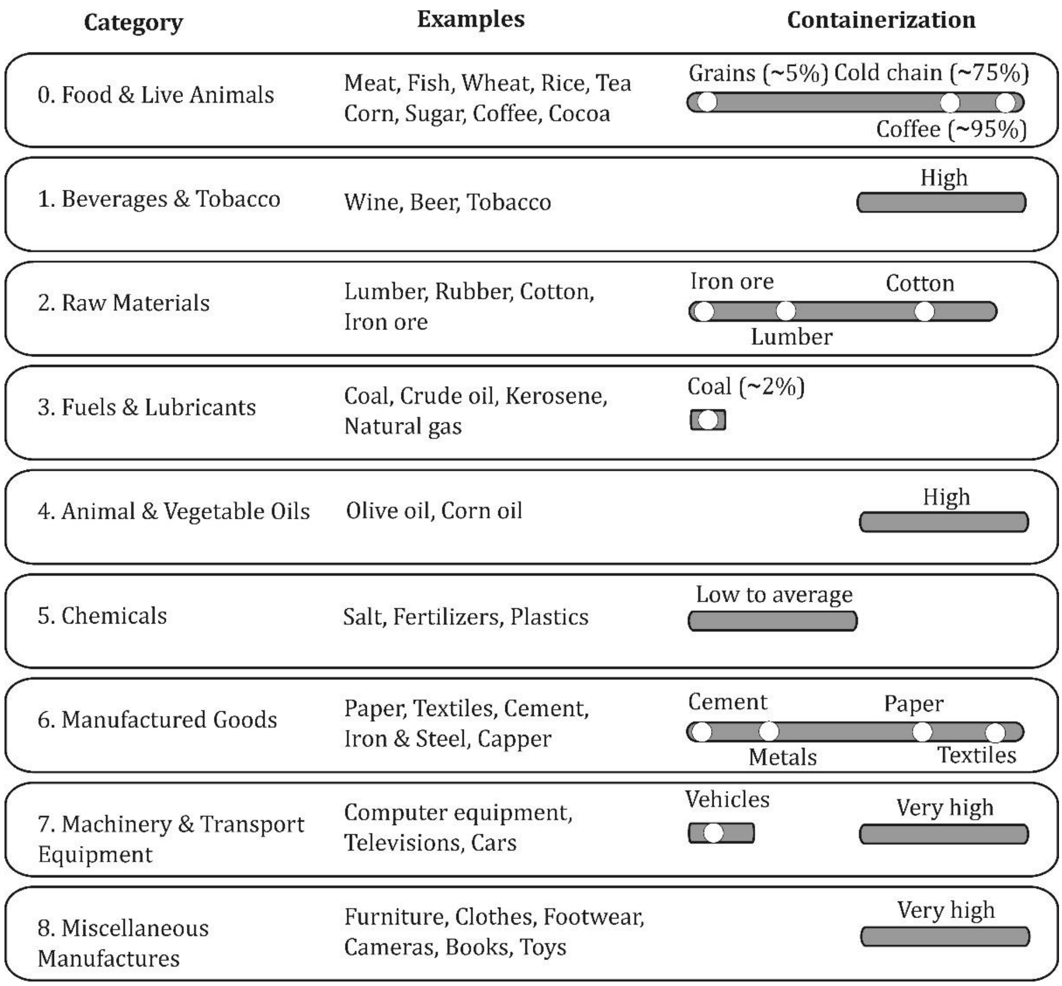

Figure 2. Commodity group and containerization level (adapted from Rodrigue, 2017)

The logistics characteristics of goods are rather straightforward since ponderous commodities, perishable, and no packable commodities are less suitable for

† SITC is a classification of the commodities being subject to international trade (source: United Nations Statistics Division)

containerization. Taking into account market characteristics, commodities with high value to weight ratio is containerization friendlies.

As it already stated the scale and scope of containerized transportation have expanded rapidly, mainly due to the technological advancement in container technology. Many segments of raw materials and food commodity chains are in the process of being containerized (Rodrigue and Notteboom, 2014). For example, food products which have not been containerized initially, through the development of refrigerated containers became containerizable in later years. Similarly to this, according to the number of projects and research papers in last decades, the trend of containerized shipping for bulk agricultural product (especially soybean) is moving upward (Liu et al., 2017; Clott et al., 2015), mainly within the context of solving the problem of empty container returning back. Hence, the process of containerization of this group of commodities is based on opportunities which have been created by empty container repositioning which assumes available number of empty containers that can be loaded for backhauls. Apart this, other factors which could have positive impact on further containerization development are (Rodrigue and Notteboom, 2014): a growing number and availability of containers in transport markets around the world; a rise in commodity prices and growing demand in new markets; fluctuations and rises in bulk shipping rates; relatively stable and even declining container shipping costs.

In regards to study given by Rodrigue and Notteboom (2014), commodities such as grain, chemicals, wood products, as well as temperature sensitive products, such as food, represent a niche for containerization. In the chapter three, some challenges in further containerization of stated commodities based on their logistics characteristics will be discussed in more detail.

2.3 Level of containerization: case of Serbia

Based on the available data, provided by the Customs Administration of the Republic of Serbia, Table 1 shows which category of goods came into the Serbia in containers in period from 2015 to 2017. Before we provide a brief analyze of presented data, the couple obstacles and assumption related to the method of data collection and keeping of Serbian Customs Administration should be mentioned. First, they don't make difference between type of containers (20 and 40 footers), they just collect data in form of "containers". Therefore, it is not possible to indicate the import of containerized goods in TEU, it could be just assumed. Second, their classification of goods is somewhat different from the classification defined by SITC, which is used in reviewed papers, so appropriate assumptions regards to this issue is also made, in order to apply SITC classification in this analysis (for example category 0 and category 1 are merged into one group). Taking into account the stated assumptions, it could be said that the top three containerized commodity groups imported to the Serbia in 2015 were: group 6 "manufactured goods"; group 5 "chemicals"; and group 8 "miscellaneous manufactures", with the percentage of total containerized imports of 57,7%; 11,5%; and 10% respectively. The similar situation was in 2016 where commodities from the groups 6 and 5 were again top two, with almost identical share of total containerized imports like in 2015, but with the difference in third-placed groups: commodities from the group 7 "machinery and transport equipment" with share of 10,6% of total containerized imports in 2016. The situation in 2017 was identical to 2016 regards list of top three containerized commodity groups, with the slightly difference in terms of percentage of total containerized imports (shown in Table 1).

Table 1. Serbian containerized imports: 2015-2017

Commodity category of import	2015		2016		2017	
	Number of containers	% of total containerized imports	Number of containers	% of total containerized imports	Number of containers	% of total containerized imports
Category 0+1	933	2,29	795	1,74	815	1,58
Category 2	3004	7,39	3082	6,75	4154	8,05
Category 4	645	1,59	543	1,18	571	1,12
Category 5	***4695***	***11,56***	***5300***	***11,58***	***9115***	***17,67***
Category 6 (only textiles)	***23464*** (21255)	***57,76*** (52,31)	***26436*** (24054)	***57,77*** (52,56)	***25350*** (23570)	***49,15*** (45,69)
Category 7	3795	9,34	***4870***	***10,64***	***6925***	***13,43***
Category 8	***4091***	***10,07***	4733	10,34	5160	10,00
Total	**40627**	**100**	**45759**	**100**	**51576**	**100**

It should be underlined the fact that the import of commodities from the category 3 “fuel and lubricants” were not containerized at all, as well as the fact that the commodity “textiles” from the group 6 was with the highest level of containerized import (about 50% of total containerized import), which is completely in line with the statements from Rodrigue (2017), as it is already shown in Figure 2.

3. THE LOGISTIC CHARACTERISTICS OF GOODS AS A CHALLENGE

The logistics characteristics of goods, as an reflection of the good's nature, could create a set of containerization challenges. First, the availability of containers as a load unit means that containers must be available in sufficient quantities and be of a suitable load unit. What kind of containers is suitable load unit for different commodities, such as grain for example, could be defined according to the diagram presented at Figure 3. The issue of containers suitability is connected to the weight of container loads (loading capacity or payload) as another major issue. The container weight is directly connected to the nature of goods which is carried by. Weight of 10 to 14 tons per loaded 20 foot container is the most common situation (Rodrigue and Notteboom, 2014). The freight nature is mainly represented by density (expressed in tons per cubic meter). At the very beginning of containerization, the 20 footers were the most used. However, due to situation that container loads are much lighter for the commodities with the higher level of containerization (such as retail commodities from the groups food, beverage and tobacco, etc.), the shipping industry has adapted to this and switched to larger container sizes (40 footers) because of their better suitability for goods with smaller density. The following diagram at Figure 3 put in the ratio container loading capacity and specific container density (expressed by the ratio of container loading capacity and volume), and it allows determination of the possible useful capacity of containers when caring goods with different density. Each container depending of its loading capacity and specific density corresponds to a certain broken line consisting of the line which passes through the beginning of the coordination system and the horizontal part corresponds to the nominal loading capacity of the container. The commodities which have a density higher than specific container density will enable their full weight utilization.

Figure 3 shows diagrams for four cargo types of containers‡: 20 ft (payload: 21630kg, volume capacity: 33.2m³, specific density: 0.65t/m³); 20 ft (payload: 2600kg, volume capacity: 33.2m³, specific density: 0.78t/m³); 40 ft (payload: 26480kg, volume capacity: 67.74m³, specific density: 0.39t/m³); and 40 ft high cube (payload: 26500kg, volume capacity: 76.3m³, specific density: 0.34t/m³), in order to determine their suitability for different commodity groups defined by their estimated average density.

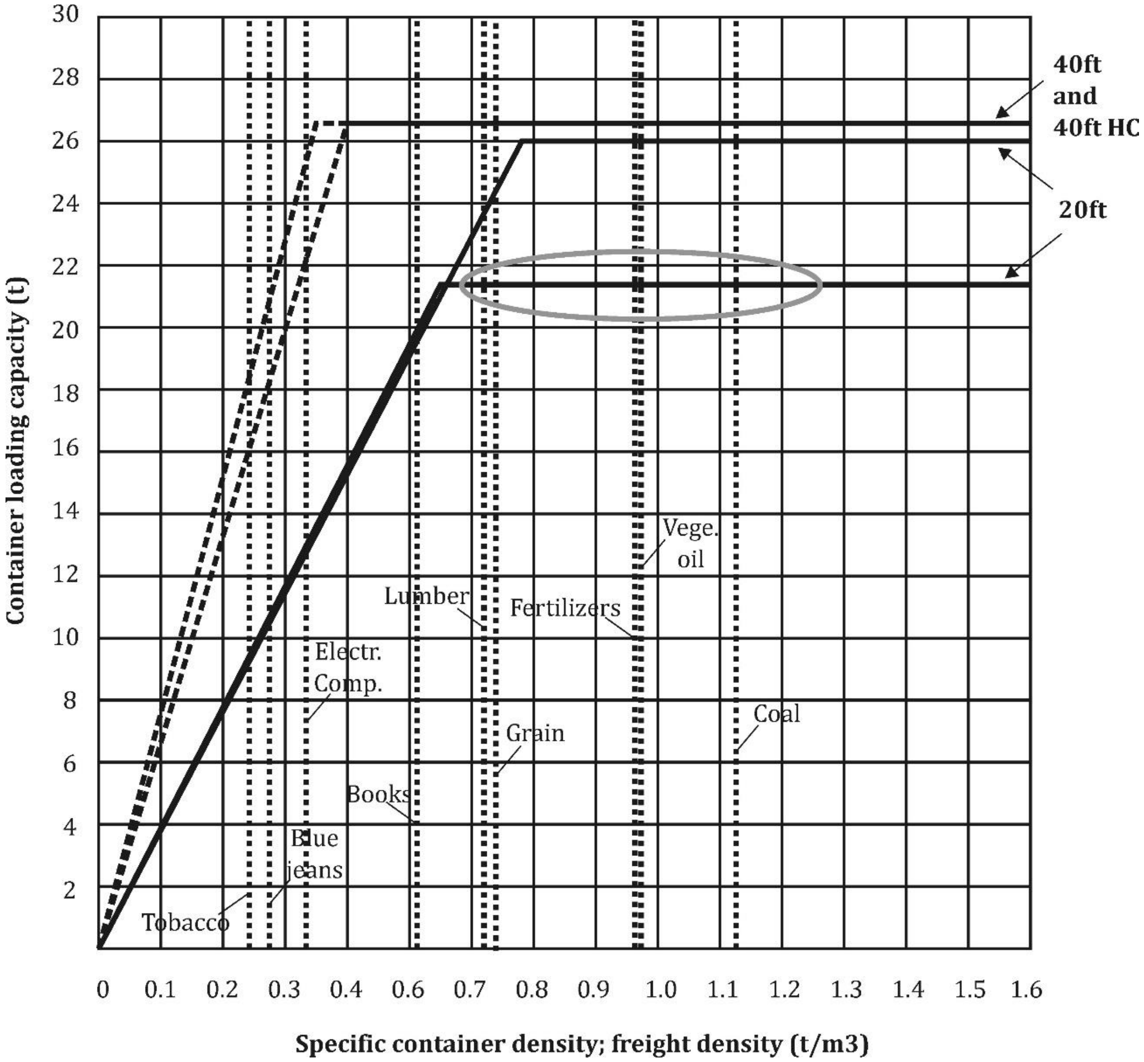

Figure 3. Diagram of loading capacity and specific density ratio for different type of containers applied for different commodity (adapted from Topenčarević, 1987)

As it is shown at Figure 3, the density of each commodity group is estimated on the basis representative goods for each group. For the commodity category 0, the representative good is assumed to be grains with an average density of 0.74 t/m³ (Rodrigue, 2012). The average freight density for other commodity groups are assumed as follows: category 1 (tobacco stems) - 0.24 t/m³; category 2 (lumber) - 0.72 t/m³; category 3 (coal) - 1.13 t/m3; category 4 (vegetable oil) - 0.97 t/m³; category 5 (fertilizers) - 0.96 t/m³; category 6

‡ https://www.modernfreight.com.cy/sea-container-specifications

(textile-blue jeans) - 0.27 t/m^3; category 7 (electronic components) - 0.33 t/m^3; and category 8 (books) - 0.61 t/m^3.

As it could be seen from the Figure 3, for ponderous commodities the 20 footer container is the most suitable, as Rodrigue and Notteboom, (2014) has already concluded. Those commodities have a density that enables the full payload utilization of 20 foot containers, as well as 40 foot containers. However, in case of 40 footers the volume capacity utilization is very low, which could have impact on shipment stability. For example, to load a 40ft container to a payload of 26.5 tons with a grain of density 0.7 t/m^3, the height to fill to inside the container would be less than 1.5m (the utilization of the volume is less than 55%). Therefore, for the commodities which represents future market potential for containerization expansion, such as grain, coal, lumber, fertilizers, the use of 20 foot containers are more structurally suited. Even the economies of scale are pushing towards the largest container possible, as it implies lower total distribution costs (including both maritime and inland carriers), the containerization of such ponderous commodities will ensure that 20 foot containers still remain on the market.

4. CONCLUSION

Containerization plays a very important role in the freight transport with a constant tendency of growth in the context of world trade. The advantages of container transport have been widely recognized since the 1980s, as a significant tool or technology which could lead to transport cost and time savings, as well as environmental sustainability. Containerization has forced even the most unavailable countries to import goods from foreign countries that can produce them at a much lower costs. It's very difficult to imagine the future of international commodity exchange without container cargo. Containerization, as one of the biggest technology revolution which hit the shipping industry in the last century, will be replaced by some unknown technology in the future, but which technology we still need to discover. Bearing in the mind the simplicity of the containerization system and standards that apply it internationally, it will probably never be fully replaced by new shipping and delivery system, but rather improved in the context of application information technology solutions. The new phase of containerization expansion in the context of both attracting of new commodity and raising the containerization level of existing ones, assuming the extraction of niche market opportunities, which will be followed by a number of challenges. The fundamental factor in the emerging containerization will be the nature of the commodities represented through their logistics and market characteristics.

ACKNOWLEDGMENT

The realization of this paper has been supported by the Serbian Ministry of Education, Science and Technological Development program through projects TR 36030 and TR 36007, as well as through project DTP1-050-3.1: “Regional and Transport Development in the Danube-Black Sea Region towards the Transnational Multiport Gateway Region (DBS Gateway Region)” supported by Danube Transnational Programme.

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THE INFLUENCE OF CHINA TO THE CONTAINER MARKET IN EUROPE

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Abstract: *European economy, which has been one of the most important ones for centuries, greatly depends on maritime transhipment. After the European Commission's data, 74 % of cargo, which arrives or departs from Europe, does so by sea and therefore, we can clearly see the importance of ports for economic growth. Over the past decades, container throughput (TEU) has become one of the most important means of transporting cargo, so ports have quickly adapted themselves – with the new equipment and better capacities. Thus, in 2000, the container handling in EU ports represented as much as 21 % of all transhipped containers in the world, meanwhile, this percentage was only 18 % in Chinese ports. Today, China has become a leading country in the container throughput, with an increase of 28 %, while the EU has fallen to 15 %.*

Keywords: *containers ports, container throughput, port competition*

1. INTRODUCTION

Europe, China and the USA (United States of America) are the most important players when we talk about international trade and economic influence. European (EU 28 countries) GDP (gross domestic product) in 2017 was 15,3 euro trillion. The population of EU countries present less than 7% of the world population, but trade with other countries presents 15,6% of global import and export. With this, we can see the importance of transport in the European economy. According to European statistics (2019), transport represents almost 5% of European GDP and offers more than 11 million jobs in this sector.

In Europe, there are more than 3000 ports and they represent the gateways to and from European network. Even if there are so many ports (such a high number of ports), 20% of cargo that comes to EU mostly goes to just three ports in the Northern part of the EU. In the last decades, container became one of the most important types of cargo and the ports adjusted their capacity to them. Today all major ports have new big container terminals with high productivity and good performance.

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In the article, is presented maritime container transport in European ports and the influence of China to it. Europe-Asia-Europe route has been increasing constantly over the last decade, reaching 24 million TEUs (twenty-foot equivalent unit) in 2017. This represents an annual increase of 6,9 % on Eastbound (Europe to East Asia) and 7,1% on Westbound (East Asia to Europe) or 7,6 million TEU on Eastbound and 16,4 million TEU on Westbound as is stated in the UNCTAD (United nations conference on trade and development) publication Review of maritime transport (2018). Most of the containers are directed to the Northern European ports (Figure 1) and a large number of European hinterland countries' maritime supply depends on them.

Figure 1. Large containers ships path density 2016-2017 in Europe (Marine Traffic)

2. CONTAINER THROUGHPUT

In 2017 the world containers throughput increased to 740 million TEU per year and presents in average 4% AGR (annual growth rate). We notice that the evaluation of container throughput in the period 2000-2017 was not steady because of the global financial crisis in 2008 (Figure 2). This crisis had a great impact on Europe and the USA but not on China. Europe needed about three years to reach container throughput from 2007, while the USA needed about two years. However, after the recovering period, European container throughput increased much faster than the container throughput in the USA. According to Shanghai International Shipping Institute (2019) China was impacted by the crisis in 2008, but they immediately started with the growth. The following year, they had a 30 % growth. The inertia of containers traffic was probably too big to slow down this development.

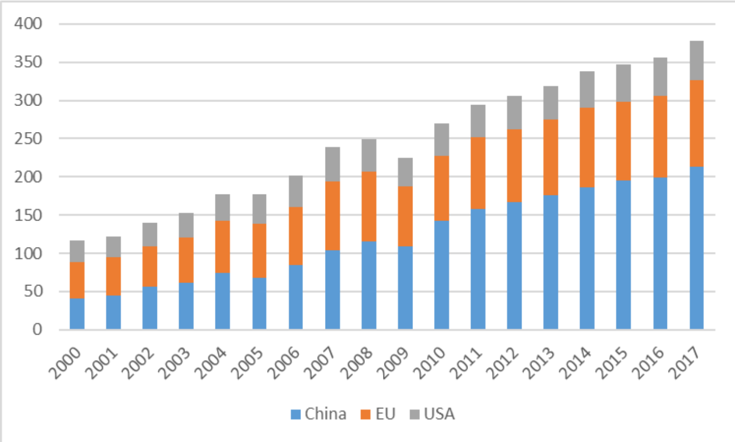

Figure 2. Container throughput in the period 2000 - 2017

In Figure 3 is presented the market share of EU, USA and China and in the last ten years, Europe lost 3,5 % of market share. Comparing with the USA which is one of the largest economies in the world, Europe has more than two times greater market share. China, which is the second largest economy in the world, in the last ten years, enlarged its market shares for 7 %.

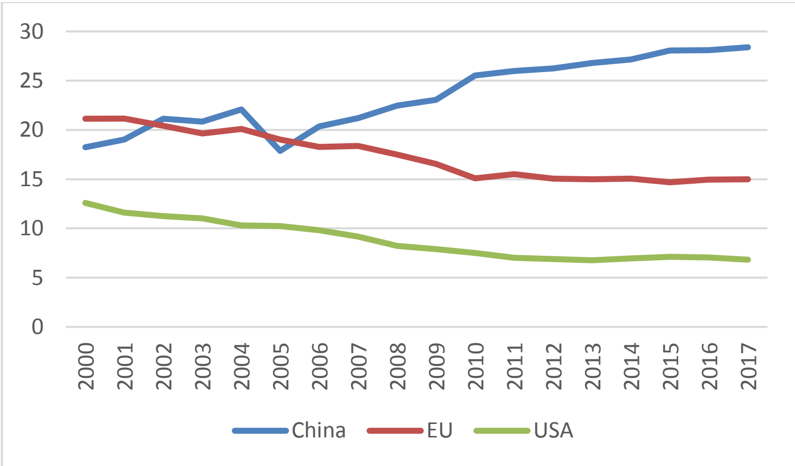

Figure 3. Container market share in the period 2000 - 2017

3. ONE BELT ONE ROAD (OBOR) INITIATIVE

One Belt, One Road (OBOR) is a strategy of the People's Republic of China (PRC) to form the so-called initiative of the economic belt of the new Land silk route and Maritime Silk Road of the Twenty-first Century (Jiang et al., 2018). The strategy was formed at the critical point of China's economic transformation. In recent years, Chinese overseas direct investment (ODI) has rapidly increased as a result of China's structural transformations and overcapacity of domestic production. OBOR is generally defined as a means of strengthening the power and expanding the Chinese enterprises in the global economy, especially in countries covered by the OBOR strategy. OBOR is focused on linking (Figure 4):

- China with Central Asia, Russia, Central and Eastern Europe and Western Europe (Land Silk Road)

- China with the Persian Gulf and the Mediterranean Sea through Central and Western Asia (Maritime Silk Road)

The Maritime silk route comprises a large maritime area that begins with the Chinese coast and extends to Europe and East Africa through the South China Sea and the Indian Ocean and reaches the South Pacific through the South China Sea. It is estimated that OBOR regions cover over 60 countries with a total population of more than 4 billion and a large share of world production (65% for the landlocked part of the Silk Road and 30% for the maritime silk route).

Figure 4. OBOR (https://safety4sea.com)

OBOR is a comprehensive economic integration plan for China with various parts of the world, in which transport infrastructure such as ports, roads, airports, railways are under development. And this all in a way that complements the interests of Beijing to develop its own infrastructure. Since the beginning of the initiative, China has become the primary source of funding for many countries in the OBOR area. According to Peng et al. (2018), the most interesting ports are located in Mediterranean, Suez Canal and Hormuz Strait. The European ports that are located in the Mediterranean, Adriatic Sea and the Black Sea will have an important role in Maritime Silk Road.

The influence of China and OBOR on Europe will be visible in the next years. Firstly, in the port throughput selected by the Chinese, and secondly in the connections with those ports and the hinterland. An example of this is the port of Piraeus in Greece.

Port of Piraeus is the first port in Europe that is controlled and wholly-owned by COSCO (China Ocean Shipping Company). In 2009 they got the Concession Agreement for Piers II and III and now they are an operator at the Piraeus Container Terminal S.A. which in 2018 reported a container throughput of 4,4 mio TEU, 19,4% more than in 2017. In the last 9 years, they invested 1 billion Euro in the modernization of the container terminal and now they plan to construct a new warehouse and to invest in the cruise terminal. As Port of Piraeus has a strategic location and could be used as a hub for Central and East Mediterranean and for the Black Sea, all investments are connected with the construction of modern infrastructure in the hinterland. Rail connection allows them a weekly train transport to Belgrade, Pardubice and Bucharest.

COSCO Shipping ports also have container terminals in some other European ports, such as Antwerp, Zeebrugge, Rotterdam, Valencia and all of them had an increase of throughput in the last year. The biggest terminal is in Piraeus, with a throughput of 833.947 TEU in 2017, followed by Euromax Terminal in Rotterdam with 666.033 TEU. In the last year, they investigated the ports in the North Adriatic – Venice and Trieste, to become one of the entry ports of Maritime Silk Road in Europe.

4. DIFFERENCE BETWEEN CONTAINER PORTS IN EUROPE AND CHINA

To define the catchment area of the ports in Europe and East Asia, we used Thiessen polygons. We used ArcGIS program to create straight line segments to connect individual port into a triangulated network. Each polygon defines an area of influence around a selected port. By creating Thiessen polygons of each port, any location inside a given area is closer to that port than to the other ports (Figure 5). We take into consideration ports in the region and population in the observed area, just to see if there are any common characteristics. In Europe, the biggest container ports are situated in northern Europe and the competition between these ports is very high as they are located close to each other and have the same catchment area. Ports in the Mediterranean area have a bigger catchment area but with a smaller population.

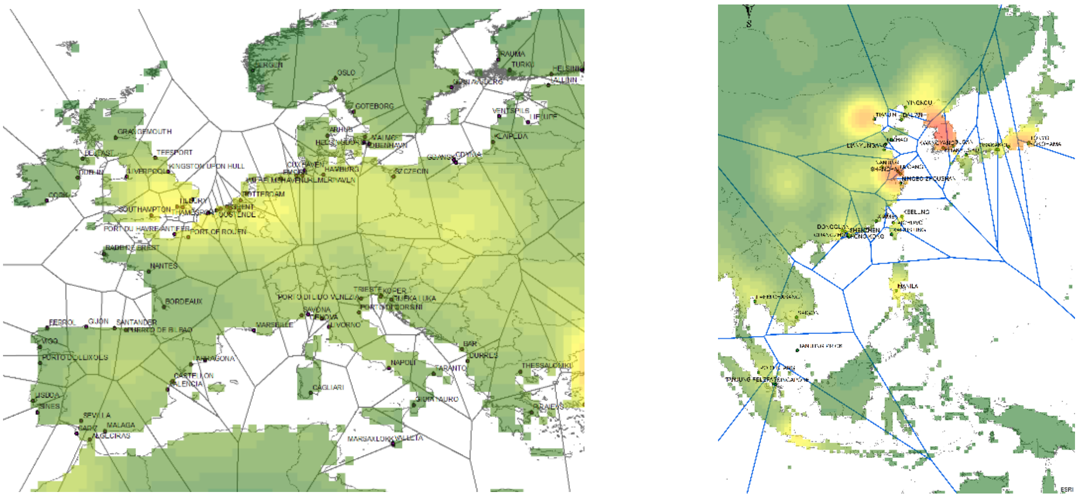

Figure 5: The port catchment area in Europe and China by using Thiessen polygons.

The biggest container ports on the world are located in China and the population of the coastal area is much higher than in Europe. The catchment area of ports in Europe and China is different and therefore it is very difficult to compare ports. This is the reason that we compared all ports together to see the difference in the period of 16 years. In figure 6, the red colour represents the total throughput of container ports in 2001, while the blue colour represents that of 2017.

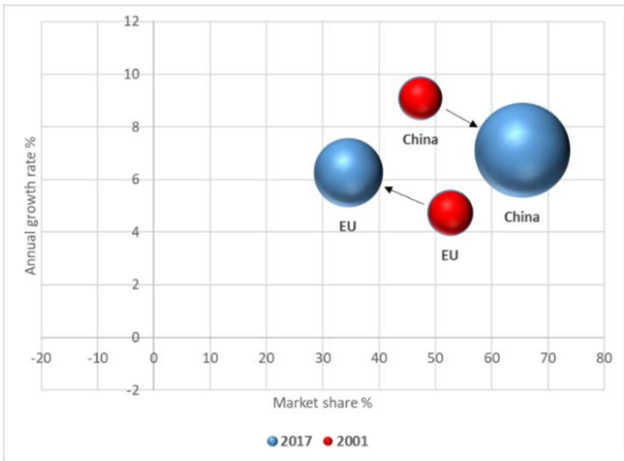

Figure 6. Position of container ports in the EU and China

In the observed period, container ports in the EU lost its market share and increased growth rate, but not enough to obtain a leadership position. Chinese container ports had a lower growth rate, but a higher market share. In the last year (2017) container throughput in EU ports was just 52% of Chinese throughput.

5. CONCLUSION

In the article is presented the analysis of container throughput in the EU and in China and the influence of China on European ports. As the OBOR initiative is an integrated scheme with an emphasis on infrastructure, it is expected that Chinese investments will increase in the silk-crossing countries. Given that major infrastructure projects are mainly initiated and coordinated by government and state-owned enterprises, Chinese state-owned enterprises are expected to be the primary force in investing in infrastructure sectors in the countries OBOR.

It is also expected that the improvement of infrastructure in the countries at OBOR will enhance the development of trade and that OBOR will facilitate international trade with government policies, in particular through the trade liberalization policy. As the container traffic is one of the most important in the trade between China and EU it is expected that this cargo will continue to increase also in the future. The importance of ports for the European economy is well known and therefore it will be necessary to pay close attention to the integration of the ports into the OBOR initiative. Future research will focus on the more detailed analysis of the port competition and on suggestions of the infrastructure investment to the port and to the hinterland connectivity.

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ELEMENTS FOR DEFINING THE INTERMODAL TERMINALS STRUCTURE

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Abstract: *In order to meet increasingly complex requirements in the fields of logistics and transport, intensive development of intermodal transport networks is necessary in which intermodal terminals (IT), as nodes in these networks, play a key role. ITs are dynamic and complex systems that can differ in terms of various elements (functions, services, subsystems, users, applied technologies, etc.) that define the different terminal structures. The subject of the paper is the comprehensive identification and classification of these elements in order to create the preconditions for defining IT typical structures and their further analysis, evaluation, comparison, etc. The paper identifies and describes 13 elements classified into four levels: organizational, operational, physical/spatial and technological.*

Keywords*: intermodal terminal, structure, element.*

1. INTRODUCTION

Trends of globalization, technological development and specialization, demographic and climate changes, etc. change the established patterns of transport processes. In order to meet the high expectations of participants in these processes, while respecting the principles of sustainable development, it is necessary to develop functional intermodal networks in which intermodal terminals (IT) play a key role. IT is a place for the transshipment and storage of intermodal transport units (ITU), change of transport mode and collecting and storage of goods. ITs are dynamic and complex systems, which can be different in terms of the large number of structural elements. In the literature, the authors were mainly focusing on one element, e.g. place and role in the network (Park & Medda, 2010; Woxenius, 1997), ownership (Rodrigue, 2014; Alderton, 1999), management model (Vieira & Neto, 2016; Monios, 2015) location (Zečević et al., 2017 , Roso et al., 2015; Brnjac & Čavar, 2009), subsystems structure (Kemme, 2013), or on a number of elements, e.g. transshipment system technologies and location (Kutin et al., 2017) or transport modes, flows volumes and resources (Wiegmans et al., 1999). However, the attempts to analyze a large number of elements (Notteboom & Rodrigue, 2009), as well as the attempts to classify them (Bichou & Gray, 2005) are rare. Using the achievements of the aforementioned researches, this paper identifies the elements for defining the IT structure and classifies them into four levels: organizational, operational,

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physical/spatial and technological. The aim of the paper was to define a comprehensive set of elements based on which it will be possible to: select those that are crucial for defining IT types, define the IT types and perform their classification, analysis, comparison, evaluation, etc. The following describes the IT structural elements.

2. ORGANIZATIONAL ELEMENTS FOR DEFINING THE IT STRUCTURE

This part of the paper describes the elements for defining the IT structure that belong to the organizational level: terminal founders and owners, organizational structure and place and role of the IT in the network/chain.

2.1 Founders and owners of the terminal

The founders and owners of the IT represent the investors, i.e. the owners of the capital used for the construction of the IT. In the literature, there are various classifications of the financing models (Beth, 1985; Alderton, 1999), but the common for all of them is the differentiation of financing by the public or private sector owned capital. Accordingly, three basic financing models can be defined: public, private and public-private partnership (PPP) (Cullinane & Song, 2002). In private financing, it is very important to realistically predict the expected flows volumes, upon which the future business of the terminal and the return of the invested funds depend. The main problems that may arise are high operating costs, especially in the initial stages of development, as well as delays or time-consuming design and construction (Rodrigue, 2014). On the other hand, the establishment of IT by the public sector can lead to the problem of constructing a larger number of ITs than necessary or their irrational location, all due to the efforts of the public sector to economically develop a region (Rodrigue et al., 2010). In addition, the problem with public financing is the lack of experience and professional staff that would manage the operation of the IT after its construction. Due to the above, in practice ITs are mostly established on the basis of PPP, which represents a business arrangement between the public and private entities, which creates the conditions for designing, constructing or financing the infrastructure (Tadić & Zečević, 2010). In this business arrangement, members of the public sector are mainly in charge of fulfilling conditions from the regulatory and legal area and providing subsidies that enable positive business operations in the initial stages of development, while members of the private sector are mainly responsible for the design, construction and operation of the IT.

2.2 Terminal management models

Terminal management involves a wider process of distributing competencies, allocating resources, and managing relationships, behavior, and activities in the IT to achieve the desired business outcome. Management models are crucial for the successful development of intermodal services by the operator, depending on its ability to cooperate, integrate, consolidate and plan (Monios, 2015). IT management models can depend on the orientation of the IT (local, regional, global), service provider, infrastructure (land, roads, rail tracks, berths, plateaus for the disposal of ITUs etc.) and superstructure (equipment and facilities in the terminal used for performing the activities) owners (public, private, PPP), who employs personnel, etc. (Vieira & Neto, 2016). This paper adopted the classification of management models based exclusively on the relationship between the owner and operator of the terminal, i.e. who employs the personnel, who owns the infrastructure and superstructure and who manages them, i.e. who makes operational decisions. Accordingly, the following basic management models are explained below (Bichou & Gray, 2005, Vieira & Neto, 2016, Monios, 2015). The d*irect management model* implies that a single entity, which owns the entire infrastructure and superstructure, directly manages all operations, functions, development and other operational activities, and employs complete personnel. *The management model through the daughter company* implies that the owner of complete infrastructure and superstructure, which is usually a public sector entity, establishes a "daughter" company that deals with daily operational decisions. The personnel is employed in the "daughter" company, and the economic entity that owns it act as a supervisor. The i*nstrumental management model* is characterized by a distribution of operational activities. One business entity, usually a public sector member, is the owner of the IT infrastructure and superstructure and employs the personnel, while other entities, usually some smaller operators, are in charge of individual operations and activities in the terminal (transshipment, transport, warehousing operations, etc.). *The leasing model* is based on the fact that one business entity is the owner of complete infrastructure and superstructure, but it gives long-term leasing to another entity (operator) who completely independently manages the terminal, makes decisions and employs personnel. *The "landlord" model* that is based on the fact that one business entity is the owner of the infrastructure and takes care of its maintenance, while another business entity (or several of them) owns the superstructure and pays the owner of the infrastructure a certain fee for its use. The owner of the superstructure independently makes operational decisions and employs personnel.

2.3 Place and role of the terminal in the network/chain

Transport systems are characterized by the movement of goods through networks where terminals represent nodes in which processes of consolidation, sorting, storage, transshipment, changes of transport means and modes are realized. These nodes can be classified in different ways, depending on the place and role in the network. This paper divides the ITs into two main groups: maritime terminals and inland terminals. Maritime terminals are located in the maritime ports and they connect parts of the maritime (*global, regional or feeder*) and land (*multifunctional, intermodal or simple*) networks, while inland terminals are nodes in the land networks connected by the road, rail or river transport modes. *Global maritime networks* directly connect ports on different continents. *Regional maritime networks* directly connect ports in the same region, or indirectly ports on different continents. In *feeder maritime networks*, smaller ports are linked to other ports in the region (regional or global) but through indirect connections. *Multifunctional land networks* include a very large catchment area spreading across the entire continent, which is connected to the port by all available modes of transport and their combinations. *Intermodal land networks* have a somewhat smaller catchment area connected to the port mainly by a combination of road, rail and river transport. *Simple land network* has a very small catchment area (mainly the territory of one state or a couple of neighboring states) connected to the port by road or rail transport. Based on the defined network categories Park & Medda (2010) defined nine basic types of maritime terminals. *Terminals in dominant ports* connect global maritime networks with multifunctional land networks and have a very large catchment area, i.e. access to global, mega-markets. *Terminals in superior ports* connect global maritime networks with limited intermodal land networks. *Terminals in intermediary ports* have direct connections with global ports on one side, but very limited simple land networks serving a small catchment area on the other. T*erminals in versatile ports* connect regional maritime networks with highly branched multifunctional land networks. *Terminals in ordinary ports* make a connection between regional maritime networks and intermodal land networks. *Terminals in developing ports* represent a link between regional maritime networks and simple land networks. *Terminals in specialized ports* are connected to feeder maritime networks on one side and multifunctional land networks on the other. *Terminals in industrial ports* make a connection between the feeder maritime network and intermodal land network. *Terminals in peripheral ports* are the simplest terminals that have very small catchment area and connect the feeder maritime network with the simple land network. On the other hand, Woxenius (1997) defines types of inland ITs according to the five basic categories of land intermodal networks. *Terminals for direct connections* are the nodes in the transport networks in which all operations are carried out at the locations near the sender and receiver, between which the direct connections are established. *Terminals for corridors* are the nodes in the networks based on the corridors (mostly of the rail or river transport modes) where flows pass through multiple terminals on a fixed route, each of which can be connected to several smaller satellite (feeder) terminals. *Terminals for hub and spoke networks* in which all flows pass through a central terminal called a hub, which is connected to a large number of satellite terminals of different sizes. *Terminal for fixed routes* in systems where all terminals in the network belong to one of the possible routes (transport lines). *Terminals for allocated routes* are the nodes in the networks in which routes are dynamically allocated in real time as a result of actual requests.

3. OPERATIONAL ELEMENTS FOR DEFINING THE IT STRUCTURE

Elements of the operational level for defining the terminal structure include the elements directly dependent on the number, type, frequency, intensity and the way of realization of the processes, activities and operations in the terminal. Elements belonging to this level are: type of cargo/transport units, structure of functions and terminal services and terminal users, which are described in more detail below.

3.1 Type of cargo/transport units

Although by the definition the ITUs are manipulated within the ITs, in practice there appears different types of cargo and transport units. Generally all cargo can be divided into containerized and non-containerized (Middendorf, 1998). Non-containerized cargo can be divided into: break-bulk, dry bulk and liquid bulk. On the other side, a special category represents the containerized cargo, i.e. the transport of various goods and materials in transport units whose composition does not change during the transport. The concept of containerization does not necessarily mean that the container is used as an ITU (Notteboom & Rodrigue, 2009). Although containers are the most common form of ITUs, terminals can be equipped or specialized for handling other ITUs such as swap bodies, parts of the vehicles (semi-trailers, railway cars) or the entire vehicles (of road, rail or water transport modes). Types of cargo and the ITUs influence the technologies and structure of the subsystems, and thus the overall IT structure.

3.2 Structure of terminals' functions and services

IT, depending on the size, flows volume and intensity, user requests and other influences, may have different functions and services. In the literature there are various ways of classifying the terminal functions (Wiegmans et al., 1999; de Villiers, 2015), and in this paper the classification made by Zečević (2006) is adopted, according to which all terminals can be divided into four categories: A, B, C and D. Terminals of category A perform the basic functions (reception, transshipment, disposal and shipping of transport means and ITUs), B perform basic and supplementary functions (e.g. ITUs charging and discharging, storing the goods, maintaining ITUs, etc.), C, in addition to the aforementioned, performs the accompanying functions (e.g. ITUs collection and dispatching, collection and distribution work with non-containerized cargo, vehicles and handling equipment maintenance, etc.), and D, in addition to all aforementioned, perform additional functions in order to achieve the complete logistics service (e.g., services with the special ITUs, educational and advisory services, planning and organization of door-to-door transport, VAL (Value Added Logistics) services, etc.).

3.3 Terminal users

Terminal users are the customers of the terminal services, which can be physical or legal entities (more often legal), owners or organizers of the freight and transport flows passing through the IT (Zečević, 2006). They can be divided into those whose core business is logistics and organization of goods transport and those whom this is not the core business. The users whose core business is logistics and transport organization can be the owners or the operators of the IT. Users whom the logistics and transport organization is not the core business can be industry, trade and other companies. Regarding the type and number of users, ITs can appear in different variants, from those with one user, through those with several users of the same type to the variants that involve a large number of different types of users.

4. PHYSICAL/SPATIAL ELEMENTS FOR DEFINING THE IT STRUCTURE

This section deals with the analysis of elements that affect the physical and spatial characteristics of the terminal, such as: location, size, territory coverage and spatial organization - layout of the terminal.

4.1 Terminal location

The successful functioning of IT depends to a large extent on its location (Zečević et al., 2017). The most comprehensive delimitation considering the location involves defining the position of the IT in relation to the macro and micro environment. In relation to the macro environment, the IT location is mostly dependent on the place and role of the terminal in the network, and accordingly, a basic division can be made to terminals located in the coastal areas and inland, as well as the division into terminals located in the urban areas, which is usually the case, and terminals in the rural areas (Teye, 2017). Regarding the micro environment, the IT location depends to a large extent on: the needs and demands of various stakeholders, mostly users, the socio-economic systems in the immediate area, as well as the position in relation to the transport corridors and logistics nodes and their connection with them. The theoretical location of the terminals in urban areas can have a wide dispersion, from the immediate urban areas to the periphery of the urban areas, whereas in relation to the traffic infrastructure, ITs can go from having weak technological connection with the transport nodes and main roads to being located within the transport nodes and on the main roads of different transport modes. In practice, however, from the micro perspective, the ITs are mostly located in industrial and commercial complexes, freight railway stations, ports, airports and freight villages (Zečević, 2006). By combining various aspects of location, various types of the IT location can be obtained.

4.2 Terminal size

The IT size can be expressed using different measures. Notteboom & Rodrigue (2009) express the IT size by the flow volumes passing through the terminal or by the area occupied by it. They also point out the strong link between the size and IT functions and state that the IT size can be expressed by the structure of functions and services it performs. On the other hand, Wiegmans et al. (1999) define the IT size in relation to the present transport modes, flow volumes, transport infrastructure within the terminal, area and the resources it has at its disposal (e.g. transport means, handling equipment). Within the ITIP project (2001), the classification of IT sizes is given based on the connections between the different transport modes and the annual flow volumes. As the flow volume appears as the most common measure for determining the terminal size, this paper adopted the classification of "small" ITs with a capacity of up to 100,000 TEU/year (Twenty-foot Equivalent Unit), "medium" with a capacity of 100,000 up to 200,000 TEU/year, "large" with a capacity between 200,000 and 400,000 TEU/year, "very large" with a capacity between 400,000 and 1,200,000 TEU/year and "mega" ITs with a capacity of over 1,200,000 TEU/year.

4.3 Territory coverage (catchment area)

Catchment area is the area of origin of the freight and transport flows which at some point pass through the IT (Zečević, 2006). One terminal can have different catchment areas for different freight and-transport flows, transport chain technologies and types of services (Zečević, 2006). The size of the terminal catchment area is defined by different factors, and the most important ones are(Zečević, 2006, Notteboom & Rodrigue, 2009): IT size, structure of the systems and services, users structure, structure and intensity of freight and transport flows, geopolitical position of the region in which the IT is located, presence and proximity of transport corridors, IT connectivity with potential customers, place and role of IT in the network, network density, etc. In relation to the size of the dominant catchment area, ITs can be divided into: local, national, international and mega (Zečević, 2006). The dominant catchment area of local IT covers the territory of a city, metropolitan area or a province in which the terminal is located. National ITs attract the flows from the territory of entire state, and international ITs from the territories of several countries, regions, part or the whole continent. The dominant catchment area of mega IT is of a global nature and can cover any territory in the world.

4.4 Spatial organization of the terminal - layout

In terms of spatial organization and subsystem positioning, ITs can appear in large number of different variants. While planning the IT, a number of parameters and potential stochastic interactions between the subsystems, potential technologies, flow volumes and structure, present modes of transport, etc. must be taken into account. In addition, there may be various constraints at the site of the IT construction, such as variations in soil quality, slope of terrain, different topology, plot shape, etc., but also the existance of infrastructural elements such as power lines, gas pipelines etc. Because of this, the layout design (planning of the subsystems' spatial organization) is a very complex process (Roy & de Koster, 2013). However, regardless of the mentioned aspects of the problem, most ITs have comparable layouts which can be classified into one of the types of spatial organization of subsystems, and according to the present transport modes, as layouts for: river/maritime-rail-road IT (Kemme, 2013), river/maritime-road IT (Zhang et al., 2016), rail-road IT (de Villiers, 2015) and river/maritime-rail IT (Wiese et al., 2011). Each type of the IT layout has a typical zone structure, which is defined in relation to the dominant functions that are being performed within them. Each zone consists of modules, i.e. organizational units that can comprise one or more subsystems or some of their parts.

5. TECHNOLOGICAL ELEMENTS FOR DEFINING THE IT STRUCTURE

This section describes in more detail the technological elements for defining the IT structure: connection of transport modes and transport chain technologies, subsystem structure and technologies of the basic terminal subsystems.

5.1 Connection of the transport modes and transport chain technologies

Modes of transport which can be present in ITs are waterborne, rail, road and much less airborne. Waterborne modes of transport can be further divided into deep-sea, short-sea, and inland waterway transport on the rivers and navigable channels (Nazari, 2005). Considering the number of present transport modes, ITs can be classified as uni-modal (only one mode of transport is present, the basic role is mostly consolidation of flows), bi-modal (connects two modes of transport, most often appear in the form of Short-sea-Road, River-Road and Rail-Road ITs), tri-modal (linking three modes of transport, most often appear in the forms of Deep-sea/Short-sea-Rail-Road and River-Rail-Road ITs) and quadri-modal (most often connecting road, rail, river and sea modes of transport) (Notteboom & Rodrigue, 2009). In addition to transport modes, it is also important to consider the technologies of intermodal transport chains because they significantly affect the technologies of subsystems in the terminal, in particular the technology of transshipment and storage. The most frequent is the container transport technology, in which a container is used as a transport unit. In addition to this, there are technologies in which parts or entire vehicles appear as transport units, and there can be (Zečević, 2006): Road-Rail, Rail-Road, Inland-River-Maritime and River-Maritime technologies.

5.2 Subsystems structure

IT subsystems are functionally organized units within the system which are responsible for the partial or complete realization of one or more functions. Examples of the IT subsystems structure defining the subsystems of water connection, storage and land connection, can be found in the literature (Kemme, 2013; Brinkmann, 2011; Steenken et al., 2004). This classification is too generalized, the subsystems are bulky and encompass a large number of different functions and are predominantly related to maritime terminals, therefore not universally applicable. Considering that the structure of the subsystem is influenced to a large extent by the structure of functions (Chapter 3.2), the IT subsystems can be classified as those for the realization of the basic, supplementary, accompanying and additional administrative and information functions. Accordingly, 4 categories of IT are defined: A, B, C and D. Category A includes group of *subsystems for the implementation of the basic functions* consisting of: infrastructure of the present transport modes, subsystems for the ITU storage, transshipment and administration of the IT. Category B, in addition to the subsystems of the category A, also includes a g*roup of subsystems for the implementation of supplementary functions*, including subsystems for: charging and discharging of containers, washing and cleaning of containers, repair, service and maintenance of containers, storage of non-containerized cargo. Category C in addition includes the *subsystems for the implementation of accompanying functions*, including subsystems for: service and maintenance of transport and handling equipment, collection and dispatching of containers, shipping and distribution activities. Category D, in addition to the aforementioned, includes *subsystems for the implementation of additional functions*, which include subsystems for: servicing of special containers, finishing, processing and other functions for goods, etc.

5.3 Technologies of the basic subsystems

Each of the subsystems implies the presence of different technological elements that enable the realization of the related functions. The technologies of the basic subsystems (transport, storage and transshipment) have the greatest impact on the other elements of the IT structure. The technologies include all processes, activities, technological requirements, mode and sequence of their realization and technological elements, which can be significantly different for various ITs. However, there are processes, procedures and requirements that are general and common to all ITs. In transport technologies, for example, these are receiving and dispatching of external transport means, internal transport between subsystems, etc. In transshipment technology, these are processes of loading/unloading of ITUs on and from transportation means, manipulations in the subsystems of charging, discharging, servicing, maintenance, etc. In storage technologies, these are the processes of disposal, storing and deployment the ITUs and other non-containerized goods, etc. These technological requirements can be realized by various technological elements, and most often these are transport and handling equipment which, depending on the requirements they realize, can be divided into equipment with dominant horizontal operation (mainly used for internal transport) and equipment with dominant vertical operation (mainly used for the loading/unloading and the disposal/deployment of the ITUs). By combining the transport (e.g. Steenken et al., 2004), transshipment (e.g. Krstić et al., 2019) and storage (e.g. Kalmar, 2011) technologies, different terminal structures are obtained.

6. CONCLUSION

The paper identified and classified the elements for defining the structure of the IT. The basic characteristics of the structural elements, and the IT categories in relation to them, are described. A total of 13 elements have been identified, which are classified into 4 levels. The purpose of defining a comprehensive set of elements is to create the basis for selecting the key elements on the basis of which IT types can be defined. By further analysis, evaluation, comparison, efficiency determination, etc., types of ITs that would represent benchmarks for the terminals which have the potential to evolve into these types, or serve as the model for the development of some future terminals, can be identified. These are at the same time the future research directions.

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MODELING THE STRUCTURE OF THE LOGISTICS CENTERS

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Abstract: *Growing competition in the global market imposes the need for proper planning of logistics processes and development of logistics networks, where logistics centers (LCs) as nodes in these network play a key role. LCs can have different structures defined by various elements characteristics, and accordingly different efficiencies. In order to identify those that would represent benchmarks for other LCs it is necessary to define the broadest set of possible structures. However, in practice a number of structures is limited, which doesn't mean there might not be some which would be competitive or more efficient than the existing ones. Therefore the goal of this paper is the modeling of potential LC structures, based on the identified dependencies between the elements characteristics and the existing structures' efficiencies. The model is tested in a case study of modeling a potential intermodal terminal structure as one of the possible LC forms.*

Keywords*: modeling, structure, logistics center, intermodal terminal, efficiency.*

1. INTRODUCTION

Due to the growing competition in the global market, adequate planning of logistics processes is crucial for defining successful business strategies. Economic development and globalization have contributed to a significant increase in the volume of goods flows between the producers and the consumers, and hence the need for planning and design of the logistics networks through which these flows would realize in the most efficient way. Logistics centers (LC), as the nodes in these networks that connect all the other participants (suppliers, manufacturers, retailers, users etc.) and different modes of transport, are the subject of numerous studies concerning their number and location (e.g. Ming-Bao et al., 2007), the structure of functions (e.g. Rimienė & Grundey, 2007), connectivity (e.g. Peng & Zhong, 2008), etc. LCs can appear in different forms and under different names, such as freight terminals, freight villages, city logistic terminals, distribution centers, free-trade zones, hub terminals, dry port terminals, intermodal terminals (IT), etc. (Zečević, 2006). Regardless of their forms and names, their structures are defined on the basis of the same structural elements, such as modes of transport, types of goods, transport technologies, the structure of functions and subsystems, etc., which may have different characteristics and modalities .

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The subject of this paper are the LC structures that need to be identified in order to create preconditions for their comparison and research on their basic characteristics, performance, efficiency, etc., in order to identify those that can serve as the benchmarks for other LCs within the groups with the mutually comparable characteristics. As the research of this type requires real data on the LC operation, they can only be implemented for centers that really exist. This, however, does not mean that there might not be structures that would be competitive with the existing ones and as such the benchmark candidates. According to this the goal of this paper is the modeling of the potential structures of the LC, based on the connections identified between the characteristics of the structural elements of the existing logistics centers and their efficiencies.

The paper is organized as follows. The following describes what the structures of the LC are, how they are defined and what they depend on. The next section describes the methodology for modeling the potential LC structures, after which it is demonstrated in the case study of modeling the potential structure of the IT, as one of the LC forms. Finally, the concluding remarks and the future research directions are provided.

2. STRUCTURE OF THE LOGISTICS CENTERS

Logistic centers represent the systems that can be different in terms of structural elements. Starting from some earlier attempts to classify these elements (Bichou & Gray, 2005), this paper classifies the elements for defining the LC structure into four levels (Figure 1): organizational, operational, physical/spatial and technological. Each of the elements can have different characteristics (modalities). By combining them in different environments and under different conditions, different LC structures can be obtained. Elements can also be used to group the defined LC structures, regardless of the different forms and names. Therefore, the groups of small, large, medium, etc. LCs can be formed in relation to the size, groups of road-rail, road-river-rail, rail-maritime, etc., LCs can be formed in relation to the modes of transport, groups of hub, corridor, liner, etc. LCs can be formed in relation to the status in the network, etc. Examples of some of the structures, that can be found in one or more of these groups, are: "small" road-rail LC that realizes the basic functions, "medium" road-rail-river LC that realizes basic and complementary functions, "large" road-maritime LC that realizes basic, supplementary and accompanying functions, etc.

These different combinations of LC structure arise as a result of a number of factors which according to their character and type of influence can be classified as: internal factors, factors of the logistic flows requirements and environmental factors (Heljedal, 2013; Bergqvist et al., 2010; Roso, 2008; Zečević, 2006). According to Zečević (2006) internal factors include: technological, spatial, financial, location and ownership/organizational performances; Factors of the logistics flows requirements include: logistics strategies, flows characteristics, quality requirements, goods characteristics and network/transport chain characteristics; Environmental factors are: spatial/economic plans, economic/organizational characteristics, laws, social factors, geographical characteristics, infrastructure characteristics, traffic and logistics characteristics, geological characteristics, climatic features and ecological factors. Factors actually define and shape the basic requirements that LC structures have to implement. Factors may affect one or more elements of the structure and may accordingly have a different significance. The excessive complexity and variety of modalities of the elements can lead to the fact that not all elements can be considered when defining the LC structures. In these situations, factors can be used to select the key elements upon which the LC structures mostly depend.

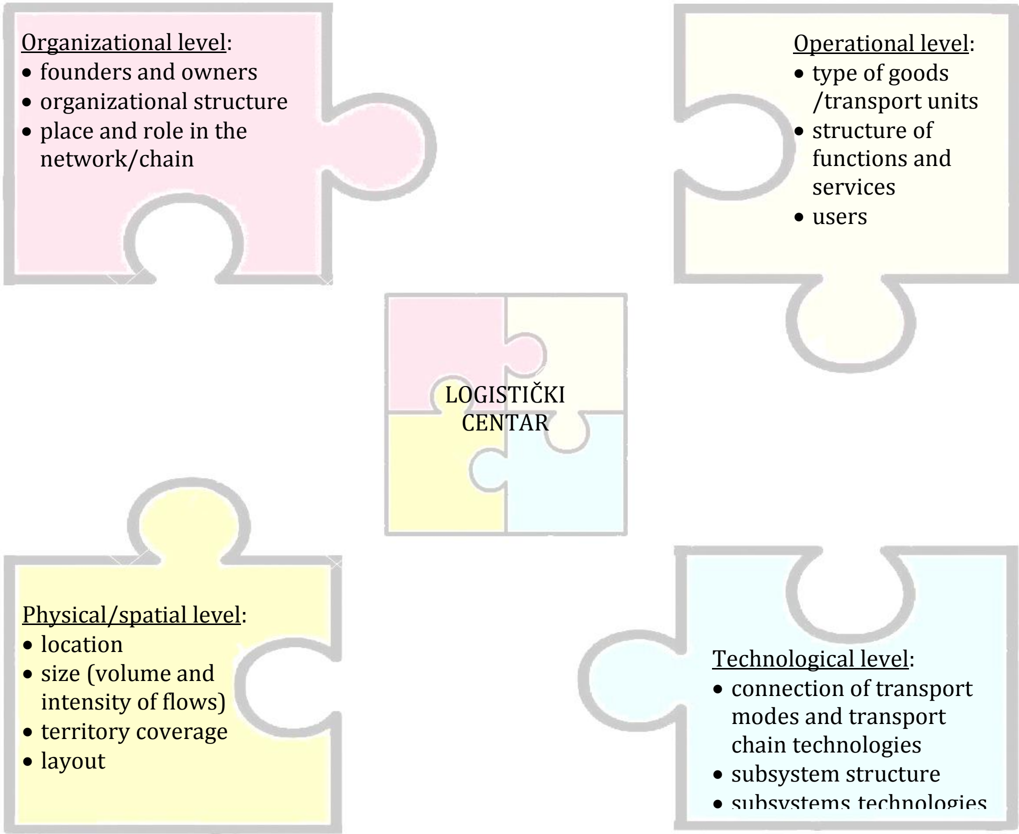

Figure 1. Elements for defining the LC structure

3. METHODOLOGY OF MODELING THE POTENTIAL LC STRUCUTURES

Modeling the potential LC structures imply the formation of structures that in practice do not yet exist, or are not yet identified and described, but which might be competitive with the existing structures. The methodology presented in this paper implies the formation of potential structures based on the existing ones. The model is based on the establishment of links between the characteristics of the LC structural elements and their efficiencies. The model actually investigates the differences in the efficiencies of various LC structures and links them to the differences in the characteristics of their structural elements, on the basis of which it forms the new (potential) structures and gives their relative efficiencies. The methodology is explained in more details below, and the schematic representation of the methodology is given in Figure 2.

The first step (Step 1) in the methodology involves the selection of comparable structures from a set of existing ones, which differ on from another by the characteristics of one of the structural elements. The next step (Step 2) is the selection of the reference existing structure, i.e. the structure that will serve as the basis for modeling the potential structure. For the selected comparable structures and reference structure, i.e. for the specific (real-life) LCs as their representatives, it is necessary to determine their efficiencies (Step 3). As the subject of this paper is not to determine the efficiencies, the methodology will go from the assumption that they have already been calculated. Efficiency can usually be obtained using one of the most commonly used tools such as: DEA (Data Envelopment Analysis) method (e.g., Serebrisky et al., 2016; Ding et al., 2015), SFA method (*Stochastic Frontier Analysis*) (e.g. Wiegmans & Witte, 2017, Cullinane et al., 2006), FDH (Free Disposal Hull) method (e.g. Wang et al., 2003), or mathematical models specifically defined for the particular problem being solved(e.g. Blonigen & Wilson, 2008).

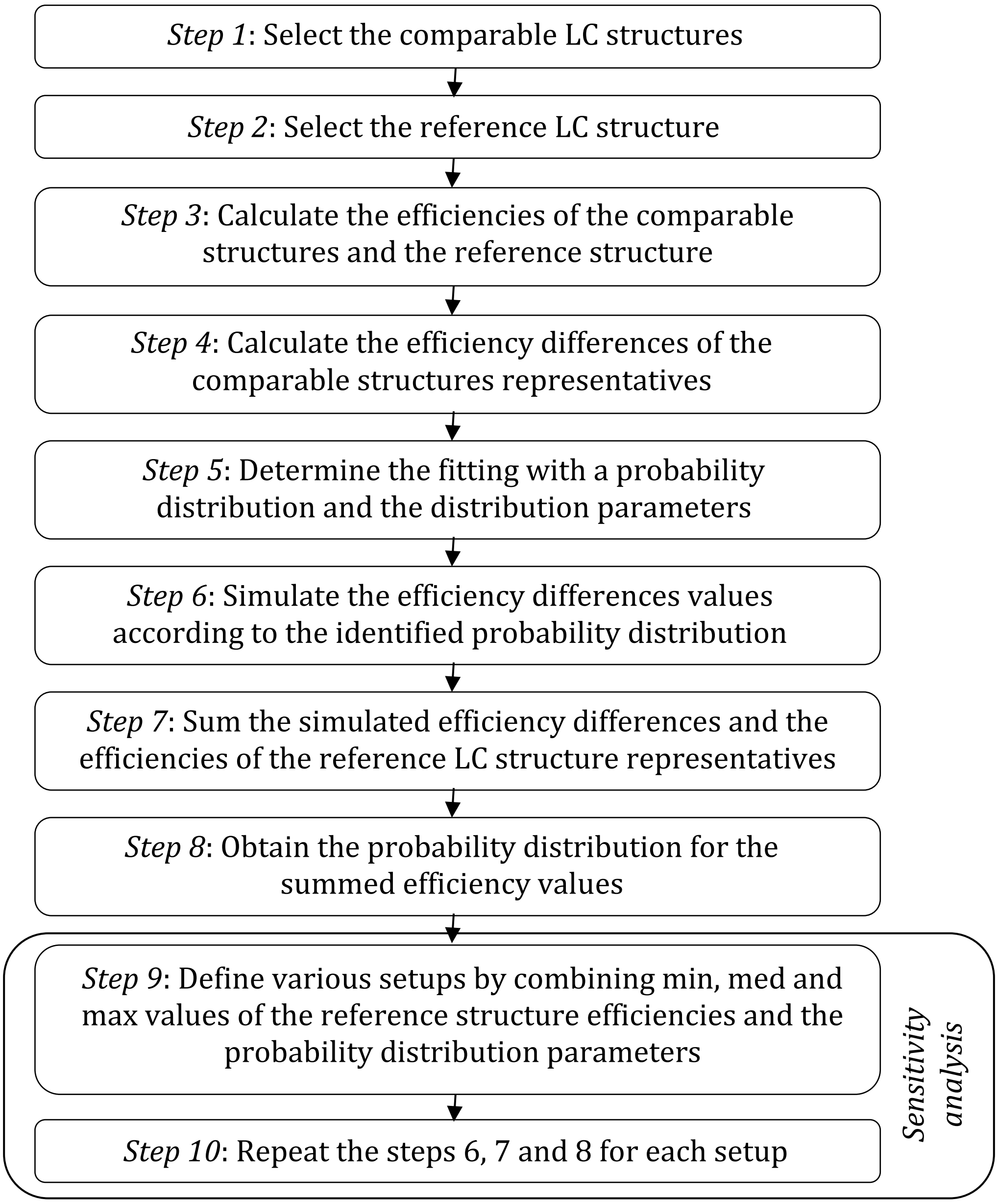

Figure 2. Schematic representation of the methodology for modeling the potential LC structures

On the basis of the obtained efficiency values, differences in the efficiency of representatives of different comparable structures are calculated (Step 4). For the obtained differences in the efficiencies, the fitting with one of the probability distribution function is checked and the parameters of this distribution are determined (Step 5). For the obtained probability distribution parameters the values of the efficiency differences are simulated (Step 6) and added to the efficiency values of the representatives of the reference LC structure (Step 7). For the obtained values, the probability distribution for the efficiencies of the LC potential structures have been formed (Step 8).

In order to perform the sensitivity analysis of the obtained results, additional settings for modeling the efficiency of potential structures are formed (Step 9). Each setting implies a different combination of the initial efficiency of the reference structure, on the basis of which the potential structure is modeled, and the parameters of the probability distribution of the efficiency difference values. In each setting, the minimum (min), medium (med) or maximum (max) values of the initial efficiencies of the reference LC's structure representatives are taken, as well as the minimum, medium or maximum values of the simulated efficiency differences, obtained by varying the parameters for the probability distribution based on which these values are obtained. For each setting, steps 6, 7 and 8 are repeated, and the probability distributions for the potential LC structure efficiency values are obtained (Step 10). As a measure for comparing the efficiency of the existing and the potential LC structures, the mean value of the obtained or simulated efficiencies can be used.

4. CASE STUDY: MODELING POTENTIAL LC STRUCTURES

The applicability of the proposed methodology for modeling the potential LC structures will be demonstrated in the case of defining the structure of the potential intermodal terminal (IT) as one of the types of LCs. IT represents a place for storage and transshipment of intermodal transport units between different modes of transport (UNECE, 2009). Based on the described elements for defining the LC structure, different IT structures can be defined. The case study to be elaborated in this paper is based on the researches by Tadić et al. (Unpublished manuscript), which define different IT structures, identify real-life European representatives for each structure and calculate the values of their efficiencies. It is also determined that the key elements, based on which the IT structures can be defined, are: size, connection of transport modes, place and role in the network and the structure of functions.

Starting from the IT structures defined in the studies of Tadić et al. (Unpublished manuscript), the first steps in applying the methodology proposed in this paper include the selection of the comparable structures and the reference structure of IT. For the comparable structures, "medium" ITs which according to the structure of functions belong to the category B, i.e. perform the basic functions (reception, transshipment, disposal and shipping of transport means and ITUs) and supplementary functions (e.g. ITUs charging and discharging, storing the goods, maintaining ITUs, etc.) (Tadić et al., Unpublished manuscript), and all "medium" ITs that belong to the category C, which in addition to the aforementioned, performs the accompanying functions (e.g. ITUs collection and dispatching, collection and distribution work with non-containerized cargo, vehicles and handling equipment maintenance, etc.) (Tadić et al., Unpublished manuscript) (Step 1). For the reference IT structure, the "medium" road-rail corridor terminal belonging to the category B according to the structure of functions is selected (Step 2). The goal was identify the effects of expanding the terminal functions structure on their efficiency, and to use this relationship to model the "middle" road-rail corridor terminal that would belong to the category C in terms of the structure of functions. The next step would be to calculate the efficiencies of the representatives of the aforementioned IT structures (Step 3), which was done in the researches of Tadić et al. (Unpublished manuscript), therefore for the purposes of this paper only differences in their efficiencies have been calculated (Step 4) For the obtained values the fitting with some of the probability distribution have been checked. A normal probability distribution with the parameters μ = 0.12 and σ = 0.219 (Figure 3) was obtained, where μ is the mean, and σ is the standard deviation (Step 5). Checking the fitting with one of the probability distribution is performed using the EasyFit software (MathWave Technologies).

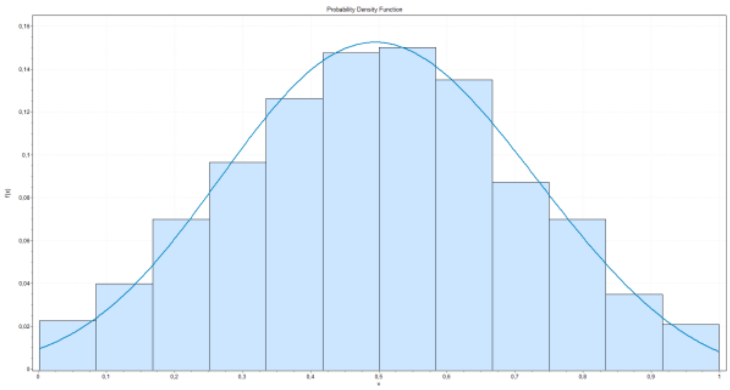

Figure 3. Check of the fitting with a probability distribution (source: EasyFit)

The values of the efficiency differences are simulated in the Excel program package for the obtained parameters. 1500 values in 1000 iterations were simulated (Step 6), and the values obtained were summarized with the efficiency values of the IT structure representatives (Step 7). In this way, the efficiency values for the "medium" road-rail corridor terminal belonging to the category C in terms of the structure of functions are obtained. The probability distribution for these values is shown in Figure 4 (designated as the "basic") (Step 8).

In order to perform the sensitivity analysis, eight more settings were created, in which the minimum, medium and maximum values of the efficiencies of the IT reference structure representatives were combined (min = 0.343; med = 0.423; max = 0.476) with the different mean values (μ_{min} = 0.08, μ_{med} = 0.12, μ_{max} = 0.16) (Step 9). For each of the defined settings, steps 6, 7 and 8 were repeated and the probability distributions shown in Figure 4 were obtained (Step 10).

For the "basic" setting, the average value of the efficiency of the potential structure of IT was 0.535. Considering the sensitivity analysis, in the defined settings, the following mean values of efficiencies were obtained 0.435 (min-min), 0.509 (wed-min), 0.544 (max-min), 0.478 (min-wed), 0.591 (max-wed), 0.497 (min-max), 0.568 (wed-max) and 0.611 (max-max). The values do not deviate significantly from the values for the "basic" setting (+/-0.1), which means that this result is acceptable. On the basis of the obtained results, the analyzed potential IT structure would be more efficient than most of the existing structures that belong to the subgroup of "medium" ITs.

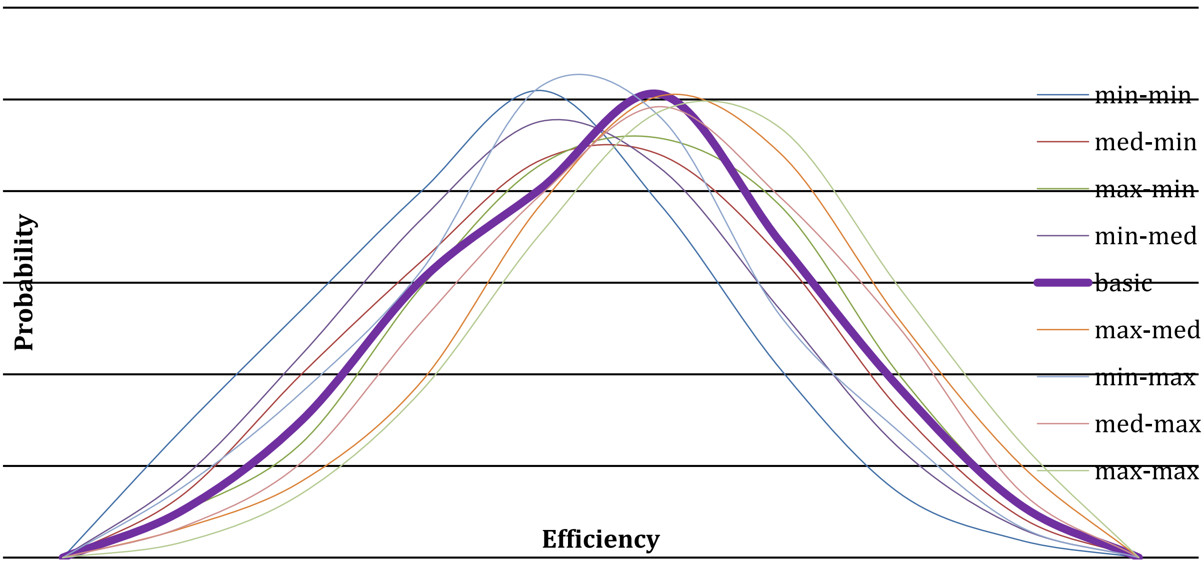

Figure 4. Simulated efficiency values for the modeled IT structure

3. CONCLUSION

Defining the LC structures allows their mutual comparison, analysis of their characteristics, performance, efficiency, etc., in order to find the most efficient ones that would serve as the benchmarks for the other existing LCs that have the potential to develop into these structures, or as a model for developing new LCs. In order for this process to be successful, it is necessary to form the widest possible set of structures, whereby it is necessary to take care not to neglect some structures that may still not exist in practice or have not been identified yet, but which could be competitive or even more efficient than some of the existing structures. Therefore, in this paper, a methodology was developed for modeling the potential LC structures and determining their efficiency, which was demonstrated on the case of modeling the potential structure of IT, as one of the possible forms of LC. Solving the case study has proven that the model is applicable and can produce potential IT structures that are competitive in terminal groups with mutually comparable characteristics. The model is also applicable to modeling other LC structures, regardless of their forms and names. Future research could address the identification of all possible structures, both for ITs and other LCs, in order to create as many structures as possible and to find the most efficient ones.

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Part IV

SUPPLY CHAINS MANAGEMENT AND REVERSE LOGISTICS

TOWARDS MORE EFFICIENT LOGISTIC SOLUTIONS: SUPPLY CHAIN ANALYTICS

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Abstract: *If something cannot be measured, it cannot be managed. This principle can be directly applied in the logistics and supply chains. Establishing and determining the logistical performance and supply chain performance represents the first step towards effective management of these systems. The second step is to use the set of contemporary analytical tools to enhance the effectiveness of logistics and supply chain processes. This is exactly the topic of this paper, since in the era of digitalization., due to the enormous amount of data generated on a daily basis, traditional knowledge and approaches cannot be used to manage logistics and supply chains. In response to technological changes and changes in business processes, the Big Data value is being increasingly studied along with the application of various analytical techniques to support the efficient flow of materials along the supply chain, that is, to effectively plan and manage the supply chain. The aim of this paper is to summarize and describe the existing knowledge about supply chain analytics and to explore how much this issue is being studied at faculties.*

Keywords*: logistics performances, big data, supply chain analytics.*

1. INTRODUCTION

The functioning of a logistic system results in the flow of materials and related information and is based on the application of various logistic strategies and the use of a wide range of resources and services within and outside individual companies. Logistics performance measures are used to determine logistic effects as well as to plan and manage logistics systems and processes. Considering that: Logistics management activities typically include inbound and outbound transport management, fleet management, warehousing, materials handling, order fulfillment, logistics network design, inventory management, supply/demand planning, and management of third-

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party logistics services providers (taken from CSCMP), a large amount of heterogeneous data from different sources is required to determine logistic performance.

Logistics management is part of supply chain management (SCM) 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 (taken from CSCMP). In modern business systems, competition is no longer between organizations, but among supply chains (SCs). Effective supply chain management has, therefore, become a potentially valuable way of securing a competitive advantage and improving organizational performance (Trkman et al. 2010). The most significant challenges for supply chain management involve the following: (i) providing visibility into supply chain performance and bench-marking; (ii) reducing operating costs through process optimization across the plan, source, make, and deliver functions; (iii) enhancing customer satisfaction by improving supply chain responsiveness and product quality (Genepakt, 2015).

Contemporary companies operate on a turbulent and very dynamic market. Under the influence of changes in business operations, primarily those caused by globalization and the increasingly shorter product life cycle as well as the requirements for product customization and sustainability, company supply chains are becoming more complex, more extended, and more global every day. Due to the increased uncertainty and competition, companies face challenges to improve operational efficiency and integrate production and distribution processes through different supply chain components. They are constantly on the lookout for new options and methods required for their logistics and supply chain management.

In the era of digitalization, due to the enormous amount of data generated on a daily basis, traditional knowledge and approaches cannot be used to manage logistics and supply chains. Web 2.0, together with Industry 4.0, cloud computing, the Internet of Things (loT), RFID and other digital technologies have led to generation, storage and transmission of large amounts of data. As the volume and complexity of data increases, so does the complexity and the time required to analyze those data and derive insight from them. In response to technological changes and changes in business processes, big data business analytics value is being increasingly studied and the application of various analytical techniques to decision making and problem-solving in business processes is being investigated. In supply chain management, there is a growing interest in business analytics as an approach that supports the efficient flow of materials along the supply chain. This is also called supply chain analytics (SCA). SCA refers to the use of data and quantitative tools and techniques to improve operational performance, often indicated by such metrics as order fulfillment and flexibility in supply chain management (Bongsug et al. 2014).

This paper aims to summarize the knowledge about supply chain analytics as a relatively new approach which, by better data management, enabled by the use of modern information and communication technologies, represents a new step towards efficient solutions in logistics and supply chains. The SCA is seen as a higher, more advanced level in the supply chain management which is accompanied by new challenges and opportunities in both business and IT. In addition, the paper examines to what extent the problems described here are studied within the university courses, i.e., what is the response of the university to the needs of the economy.

2. SUPPLY CHAIN ANALYTICS

The widespread use of digital technologies has led to the emergence of big data business analytics as a critical business capability to provide companies with better means to obtain value from an increasingly massive amount of data and gain a powerful competitive advantage (Wang et al. 2016). The study of big data is continuously evolving and the main attributes of big data have been characterized by what is called 5Vs concept consisting of: volume, variety, velocity, veracity, and value (Nguyen et al. 2018; Tiwari et al. 2018). Volume refers to the magnitude of data generated; the volume of digital data is growing exponentially and is expected to reach 35 Zeta bytes by 2020 (Arunachalam et al. 2018). Variety refers to the fact that data can be generated from heterogeneous internal and external sources, in structured, semi-structured, and unstructured formats (Nguyen et al. 2018). Velocity refers to the speed of data generation and delivery, which can be processed in batch, real-time, nearly real-time, or stream- lines (Nguyen et al. 2018). Veracity stresses the importance of data quality because many data sources inherently contain a certain degree of uncertainty and unreliability (Nguyen et al. 2018). Value refers to finding new value contained in the data which can be used for better business planning.

Big data analytics (BDA) involves the use of advanced analytics techniques to extract valuable knowledge from vast amounts of data with variable types in order to draw conclusion by uncovering hidden patterns and correlations, trends, and other business valuable information and knowledge, in order to increase business benefits, increase operational efficiency, and explore new market and opportunities (Nguyen et al. 2018; Tiwari et al. 2018). BDA is not new since various quantitative techniques and modeling methods have long been used in business processes (Souza, 2014). From 1950 to 2010, the complexity of data has increased gradually, and as a result, BDA has emerged as a flagship technology to tackle BD challenges (Arunachalam et al. 2018).

In recent decades, under the influence of technological development, globalization and increasingly demanding customers, new structures and strategies have been developed in the production, logistics and SCM. Business paradigms have also changed accordingly. This development is largely enabled by the revolutionary development of information and communication technologies. Figure 1 shows typical periods (with a brief description) in the evolution of logistics, SCM and BDA.

In accordance with the needs of modern business systems and with respect to the fact that logistics is the basic driver of SCs, improving the performance in these areas has become a continuous process that requires an analytical performance measurement system. Increasing logistics and supply chain efficiency begins with establishing, determining, and enhancing basic metrics and reporting, as they provide essential data for performance improvement initiatives. Nowadays the volume of data in every supply chain is exploding from different data sources, business processes and IT systems, including enterprise resource planning (ERP) systems, distributed manufacturing environments, orders and shipment logistics, social media feeds, customer buying patterns, and technology-driven data sources such as global positioning systems (GPS), radio frequency based identification (RFID) tracking, mobile devices, surveillance videos, and others (Editorial Board, 2018). Digitalization is present in all spheres of human activities and when it comes to business activities then digitalization is a personification of the concept Industry 4.0 (Maslarić et al. 2016). As the amount of data becomes larger, more diverse and more complex the need to manage and analyze them becomes more challenging in order to deliver useful business insights.

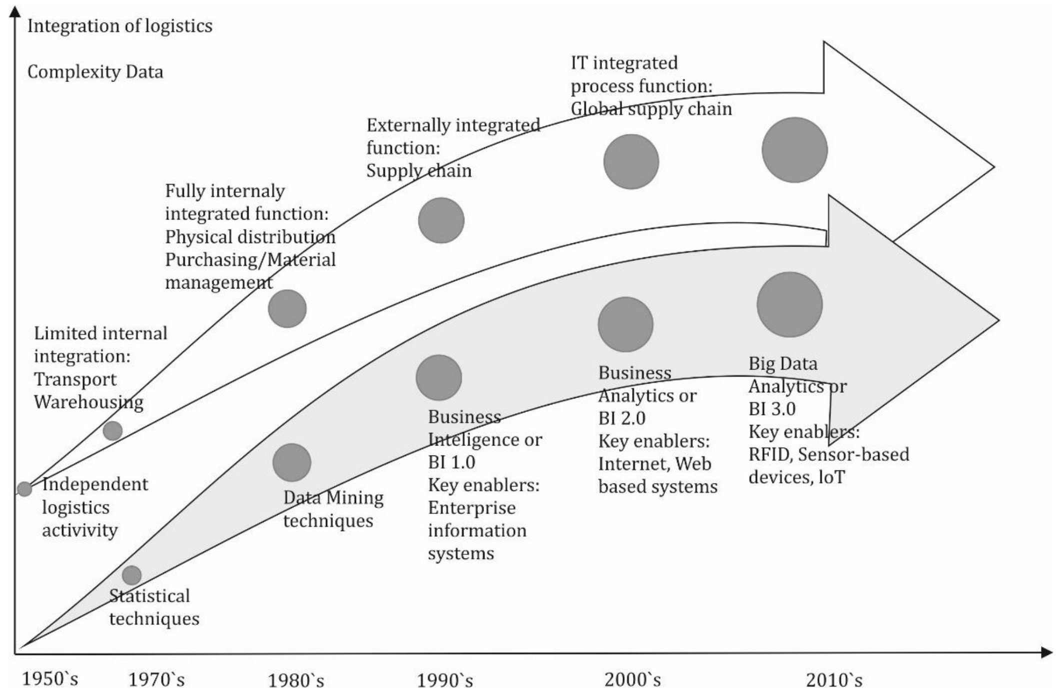

Figure 1. Evolution of logistics, SCM, and BDA (adapted from Arunachalam et al. 2018)

The business uncertainty (market conditions) is among the most important challenges facing modern SCs, and it poses considerable difficulties in terms of SC planning and control. All this has led to the growing interest in big data analytics in the management of logistics and supply chains i.e., for establishing supply chain analytics (SCA). SCA represents a more advanced level in the management of logistics and supply chains, not only as a way to improve performance but also to gain new knowledge. SCA represents a group of approaches, organizational procedures and tools, which are used together to get information, analyze this information and predict the outcome of solutions in different SC areas (adapted from Arunachalam et al. 2018). In the strategic phase of supply chain planning, SCA has been applied to help companies make strategic decisions on sourcing, supply chain network design, as well as on product design and development. In the operational planning phase, SCA has been used to assist management in making operation decisions, such as: demand planning, procurement, production, inventory, and logistics (Wang et al. 2016). The supply chain alone produces a large enough data set that analytics can be applied not only in reporting but also in better predicting of future challenges.

Supply chain analytics focuses on the use of information and analytical tools to make better decisions regarding material flows in the supply chain (Souza, 2014). Analytics techniques can be categorized into three types: descriptive, predictive, and prescriptive:

- Descriptive analytics describes what happened in the past and derives information from significant amounts of data to answer the question of what is happening. On the basis of real-time information about locations and quantities of goods in the supply chain, managers make decisions at the operational level (e.g. they adjust the schedule of shipments, deploy vehicles, issue orders for restocking products, etc.)

(Souza, 2014). Common examples of descriptive analytics are reports that provide historical insights regarding the company's production, financials, operations, sales, finance, inventory, and customers (Tiwari et al. 2018).

- Predictive analytics uses historical data to determine the probable future outcome. Predictive analytics in supply chains derives demand forecasts from past data and answers the questions related to what will be happening or what is likely to happen (Tiwari et al. 2018). It exploits patterns found in the data to identify future risks and opportunities and predict the future. This is used to fill in the information that is missing and to explore data patterns using statistics, simulation, and programming.
- Prescriptive analytics derives decision recommendations based on descriptive and predictive analytics models as well as on mathematical optimization, simulation or multi-criteria decision-making techniques. It goes beyond predicting future outcomes by also suggesting action to benefit from the predictions and showing the decision maker the implications of each decision option. Prescriptive analytics answers the question of what should be happening.

Statistical analysis, simulation, and optimization are popular techniques in SCA. In addition, we should also mention association rule mining, clustering algorithms, support vector machine, neural networks, fuzzy logic, text mining, sentiment analysis, feature selection, etc. (Tiwari et al. 2018).

2.1 Supply chain analytics in published papers

Since 2010 SCA has attracted a great deal of attention on behalf of academic and professional public. This is indicated by a large number of papers published in scientific journals and presented at conferences as well as by the results of research on the application of SCA in practice. The published papers deal with different aspects of SCA such as big data attributes, the influence of big data analytics on logistics and supply chain performance, and implementation issues and supply chain capability maturity with big data.

One of the first papers written on this topic is by Trkman et al. (2010). Their paper investigates the relationship between analytical capabilities in the plan, source, make and delivery area of the supply chain (based on the Supply Chain Operations Reference model - SCOR) and business process orientation as moderators. The results provide a better understanding of the areas where the impact of business analytics may be the strongest. Bongsug et al. (2014), approach SCA as an integration of three types of resources: data management resources, IT-enabled planning resources and performance management resources and investigate the relationships between these resources and supply chain planning satisfaction and operational performance. The findings of their research offer vital information towards a better understanding of the role of business analytics for supply chain management and its impact on operational performance. Wang et al. (2016) assess the extent to which SCA is applied for the management of logistics and supply chains depending on the maturity of the SCA. They emphasize SCA's strategic importance as an asset that enables integrated business analytics of the company.

Several papers have also been published so far that provide an overview and systematization of academic literature on big data analytics and supply chain. Tiwari et al. (2018) investigate big data analytics research and application in supply chain management between 2010 and 2016 and provide insights to industries. In terms of future research in this field, a paper by Nguyen et al is particularly interesting as it proposes a novel classification framework that provides a full picture of current literature on where and how BDA has been applied within the SCM context (Nguyen et al. 2018). A critical review of the literature written by Arunachalam et al. (2018), is focused on understanding the multiple dimensions of BDA capabilities in the supply chain. The paper presents a conceptual model of maturity that explains five dimensions of BDA capabilities: data generation capability, data integration and management capability, advanced analytics capability, data visualization capability, and data-driven culture.

Traditionally, supply chains have been managed by transactional systems, like ERP/SCM systems which are meant to run operations in an automated fashion, not to analyze data for predictive insights. These transactional systems are significant components of SCA, which may have contributed to the fact that in practice the ability to report is frequently wrongly identified as analytical ability. The fact is that there are many levels of analytics covering a whole spectrum of capabilities from standard reporting and alerts all the way to statistical analysis, forecasting, predictive modeling, and optimization.

By applying SCA companies strive to achieve different goals. The results of a survey carried out by APQC which included experts in the supply chain from 36 sectors show that companies have several areas that they focus on in SCA application (Figure 2). In addition to supply chain performance improvement, organizations are looking at analytics as a means of better dissemination of information. According to the results of this survey, descriptive analytics is most widely used in all areas of the supply chain, predictive analytics is used less for certain functions (for the functions of supply chain planning and procurement), while prescriptive analytics is used to a lesser extent (APQC).

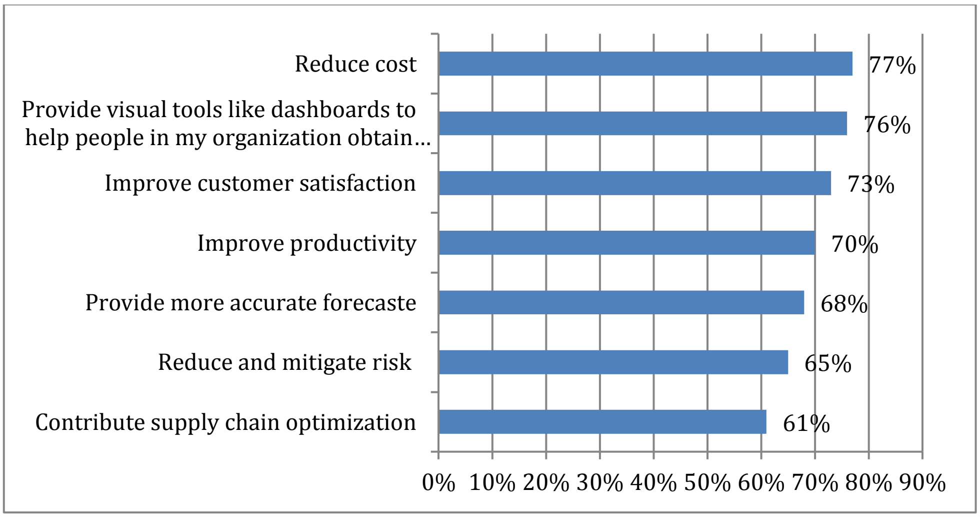

Figure 2. Areas of focus for supply chain analytics (APQC, 2017)

Nguyen et al. (2018) considered in their work, among other things, the representation of different types of analytics in published scientific papers (the review covered 88 papers) and concluded that prescriptive analytic was most often discussed, as shown in Table 1.

Table 1. Level of analytics in each SC function (Nguyen et al. 2018)

	Descriptive	Predictive	Prescriptive	**Total papers**	In %
Procurement	3	5	2	10	11.36
Manufacturing	4	7	12	23	26.13
Warehousing	3	3	6	12	13.64
Logistics/transportation	4	6	15	25	28.41
Demand management	2	10	0	12	13.64
Other SC topics	2	0	4	6	6.82
Total papers	18	31	39	88	100.00
In %	20.45	35.23	44.31	100.00	

2.2 Supply chain analytics in university curricula

Supply chains are becoming more complex, more extended, and more global every day so that adequate logistics are needed for logistics and supply chain management and their adjustment to business changes. Creation and implementation of educational programs, which besides traditional knowledge from logistics and SCM include contemporary topics in this field (which are caused by technical, technological and business changes), presents the challenge and challenge for universities and their response to the demands of the economy. SCA is one such topic. In this paper, a short study of curricula at EU universities related to SCA was conducted.

As SCA presumes that the students possess an appropriate level of knowledge in the areas of logistics, SCM and mathematics, and that SCA enables the acquisition of new knowledge and skills, it is planned that the research focuses on master and doctoral studies at European universities. The search was carried out over the Internet using the following key words: master in logistics, and master supply chain management. In this way, a list of 45 faculties in Europe that has master studies in logistics and/or supply chain management has been obtained (taken from Masterstudies.com). The structure of the subject in master studies for all selected faculties is reviewed, and analyzed. The results thus obtained are shown in Table 2. It can be concluded that at European faculties with master studies of logistics and supply chain management, about 50% of them there is a subject SCA, other related subjects or SCA master's program. The same procedure was applied for the level of doctoral studies, however, obtaining valid data, because of the specificity of organizing this level of study, requires a different approach, so in this paper, this area has not been processed.

Study programs at the master level in the Republic of Serbia are reviewed by the Universities of Belgrade (Faculty of Transport and Traffic Engineering, Faculty of Economics, Faculty of Mechanical Engineering, Faculty of Organizational Sciences), Novi Sad (Faculty of Technical Sciences, Faculty of Economics), and Niš (Faculty of Economics, Faculty of Mechanical Engineering). Only at master studies at the Faculty of Transport and Traffic Engineering, there are related subjects with SCA (on the other faculties there are not related subjects with SCA). It should be noted that at the Faculty of Organizational Sciences there is master’s program Business analytics.

Table 2. SCA subjects to master studies at European faculties

	Number of faculties	In %
No data	5	11.11
There is not SCA master's program	18	40.00
There are related subjects	18	40.00
There are a subject SCA and other related subjects	2	4.44
There is SCA master's program	2	4.44
Total faculties	45	

Considering the wide scope of logistics and SCM, a positive response from the European faculties to the requirements of training in the logistics of logistics managers from the Big Data analytics and supply chain can be noted. It should be the guideline of faculties in the Republic of Serbia.

3. CONCLUSION

Data analysis is crucial for decision-making in all business applications. At the time of digitalization the volume of data in every supply chain is exploding from different data sources, business processes, and IT systems. Big data analytics uses more sophisticated computational techniques to handle complex data that has been increasing on a large scale, and unable to be processed using traditional methods. In logistics and supply chain management, there is growing interest in business analytics based on big data.

A brief overview of the papers showed the great interest of scientists to understand the various aspects of SCA in the management of logistics and supply chains. Surveys in practice show that companies expect from SCA better predictions and thus respond to them proactively, increasing both efficiency and profitability. Obviously, this topic will be much more explored.

Research of SCA curricula at universities in Europe has shown their positive response to the requirements of practice in the field of education of logistics and supply chain managers in this field. It should be the guideline of faculties in the Republic of Serbia.

ACKNOWLEDGMENT

The study was financially supported by the Serbian Ministry of Education and Science (Project No. TR36030).

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INFLUENCE OF PRODUCT AND BUSINESS ENVIRONMENT CHARACTERISTICS ON MANAGING SUPPLY CHAIN VULNERABILITY

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Abstract: *Increased changes of trading rules in a global economy, more frequent adverse weather events due to climate change, and other unexpected events add more uncertainty to the ever-present logistics challenges for companies to manage their supply chains. Thus, there is increased theoretical and practical interest to prevent disturbances of logistics operations, as well as to manage disturbances when they occur and avoid supply chain vulnerability. Decreased vulnerability of supply chains is desired as it leads to robust and resilient supply chains. The objective of this paper is to understand how contextual factors, i.e., product and business environment related factors affect relationship between redesign strategies and vulnerabilities in the supply chain. We consider typical redesign strategies, such as the adoption of assurance systems, the use of proactive control, use of redundancy, or enhancing flexibility in supply chains. Seen from the lens of contingency theory, the findings from our literature review suggest that contextual factors affect the link between redesign strategies and vulnerabilities in the supply chain, but further research is needed to examine how each of the contextual factors affect selection and implementation of each redesign strategies used to manage supply chain vulnerabilities.*

Keywords: *Contingency theory, Prevention of disturbances, Impact reduction*

1. INTRODUCTION

Studies in the supply chain management discipline conducted over the past decades show that an increased focus on efficiency and leanness of supply chain processes has resulted in an increased vulnerability of supply chains to risks and disturbances (Stecke & Kumar 2009). Vulnerable supply chains suffer from a negative impact to their performance, i.e. they are not robust (Kleindorfer & Saad 2005). Ability to recover from these disturbances or to improve performances beyond previous levels, indicate their resilience (Vlajic 2017; Christopher & Peck 2004). Robust and resilient supply chains are able to predict and

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detect relevant disturbances in their processes, to respond fast, and to redesign their supply chains quickly (Blackhurst et al. 2005). However, the literature suggests that choice and success of implementation of redesign strategies might be a subject to contextual factors (Sousa & Voss 2008). This approach indicates suitability of contingency theory to explain effects of the contextual factors. The contribution of our study is the application of this theory in the area of supply chain vulnerability, as most of the identified studies applied contingency theory to the manufacturing strategy (Sousa & Voss 2008).

Thus, the *research objective* of the study is to investigate how contextual factors related to the product and business environment characteristics affect link between prevention and mitigation redesign strategies and vulnerability of a supply chain.

The remainder of the paper is structured as follows: First we present a literature review and a theoretical foundation. Subsequently, we briefly present the choice of a methodology to help achieving our research objective. In the concluding section we present the key idea, the propositions that result from the literature and possible future research.

2. LITERATURE REVIEW AND THEORETICAL FOUNDATION

To explain the model (Figure 1), we depart from a supply chain scenario and its vulnerability. In line with (van der Vorst 2000; Vlajic et al. 2016), we define a *supply chain scenario* as the configuration of four elements of the supply chain: 1) *the managed system*: the physical design of a network of facilities and all other elements that perform logistic activities (e.g. equipment, vehicles, and people), including inventory; 2) *the managing system*: the planning, control and co-ordination of logistic processes in the supply chain while aiming to achieve strategic supply chain and logistics objectives within the restrictions set by the network design; 3) *the information and decision support systems* within each decision layer of the planning and control system, as well as the information technology infrastructure needed; and 4) *the organizational structure* within the supply chain as well as the coordination of tasks in order to achieve defined objectives.

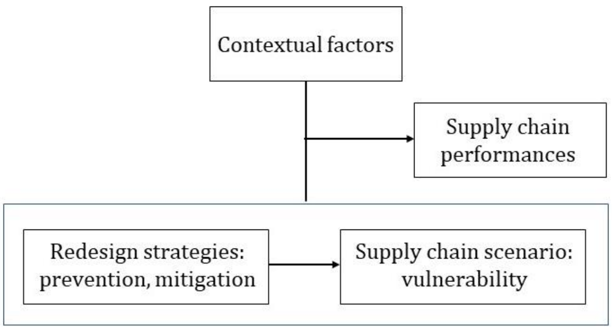

Figure 1. The model

This supply chain scenario is subject to various risks and disturbances that negatively affect supply chain performances and cause supply chain vulnerability. Failure of a production or logistics equipment, decision making errors, supplier failures, accidents, etc. are typical examples within a wide range of possible risks and disturbances. To manage this vulnerability, redesign strategies can be implemented. For example, Hopp (2008) recommends strategies to manage disturbances in the context of their likelihood and consequences: in the case of minor consequences, regardless of the likelihood of disturbances, companies should do nothing; in the case of medium to severe consequences a choice of strategies depends on the likelihood of these disturbances: buffering/pooling is recommended in the case of a high likelihood, contingency planning in the case of a medium likelihood and crisis management in the case of a low likelihood. While this can be accepted as a general principle, buffering appears to be costly for high value products (Lovell et al. 2005), and very limited in the case of perishable products. The success of pooling might depend on the readiness for collaboration between various supply chain members (Cao & Zhang 2011). Thus, the use of redesign strategies to manage disturbances is context dependent, and *contingency theory* might explain this dependency (Sousa & Voss 2008).

Thus, to manage supply chain vulnerability, it is important to understand how contextual factors affect choice and the use of redesign strategies to manage vulnerabilities of the supply chain scenario. This is in line with Chang et al. (2015) who stated that a 'one size fits all' approach does not fit with the selection, application and effectiveness of the redesign strategies.

Generally, we propose that contextual factors might act as vulnerability sources or they can hinder application of redesign strategies, which might amplify supply chain vulnerability. They can also enable or contribute to easier implementation of redesign strategies that prevent or mitigate disturbances and result in robust and resilient supply chains. A supply chain is considered to be *robust* when a disturbance of supply chain processes does not impact significantly the supply chain performances (Vlajic et al. 2016), and it is considered *resilient* when a disturbance of supply chain processes impacts the supply chain performances, but they are restored to the same or better level after the recovery period (Christopher & Peck 2004).

In this paper, we consider product and business environment related factors as the relevant contextual factors to manage supply chain vulnerability (Inman & Blumenfeld 2013), and a set of guiding principles that can help managing supply chain vulnerability. In the remainder of the paper, we explain this in more detail.

2.1 Guiding principles towards achieving robust or resilient supply chains

In general, the most common guiding principles to manage disturbances in logistics processes correspond to traditional risk management approaches. Two basic principles are a) reduction of the probability/frequency of a risk or disturbance occurrence and b) reduction of the severity of an impact (Norrman & Jansson 2004). We explain these concepts in more detail below.

- Cause oriented, preventive guiding principle and related strategies

The *cause-oriented principle* attempts to reduce the probability a disturbance occurring by addressing its causes; this principle is preventive in nature (Wagner & Bode 2009; Vlajic et al. 2016). It is based on the premise that if possible, probable causes of disturbances need to be avoided or minimized (Waters 2007). General views associated with this principle are: 1) proactive redesign strategies are used in relatively more predictable environments (Ketokivi 2006) and 2) disturbance prevention should precede disturbance impact reduction (Kleindorfer & Saad 2005). However, as Lewis (2003) argues, the complexity of causal events and the variability associated with negative consequences suggest that prevention alone will never suffice. Some events can never be predicted and some stakeholders will always face losses. Lewis also observed that too much reliance on prevention and mitigation actually results in a less effective overall recovery.

Typical strategies that belong to this group are assurance and reliability systems and proactive control and monitoring.

- *Assurance systems*. Generally, best practices in an industry represent strategies typically employed as assurance systems. For example, they typically tackle use of primary packaging to protect a products from a damage (Williams & Wikström 2011), or training staff to conduct proper material handling.
- *Proactive control and monitoring*. Proactive control is based on the consideration of supply chain risks in the decision-making process (Inman & Blumenfeld 2013), in such a way that vulnerability sources are avoided or probability of a detrimental unexpected events is minimized. Typical examples of proactive control are: strategic sourcing, vendor rating, strict supply contracts, information sharing and integrating practices, as well as monitoring suppliers and controlling business opportunities (Harland et al., 2003), product simplification and improved demand forecasts (Inman & Blumenfeld 2013). Proactive control relies on tools based on statistical process control and control charts (Christopher and Lee, 2004), data mining, intelligent web agents and expert systems (Blackhurst et al., 2005), as well as use of Internet of Things and Big data.

• Effect oriented, impact reductive guiding principle and related strategies

The *effect-oriented principle,* also known as the impact reductive principle (Kleindorfer & Saad 2005; Vlajic et al. 2016) attempts to limit or mitigate the negative consequences of disturbances (Wagner & Bode 2009). Generally, it is grounded on two ideas:

- To make supply chains sturdy and strong, so that their performances are not affected by disturbances (robust supply chains); the key strategy here is related to building *redundancy* in the supply chains (Sheffi & Rice Jr. 2005). This is typically ensured by increasing inventory or time buffers (Inman & Blumenfeld 2013), keeping multiple suppliers (Rice Jr. & Caniato 2003; Tang 2006), and adding capacity (Zsidisin & Wagner 2010; Chopra & Sodhi 2004)
- To enable fast recovery of supply chain performances after the disturbance occurred (resilient supply chains); the key strategy here is related to enhancing flexibility (Zsidisin & Wagner 2010), i.e. having ability to change elements of a supply chain scenario by ensuring that a disturbance is identified (Barker & Santos 2010) (information sharing aspect) and a response is put in place (responsiveness aspect). Key strategies related to flexibility are switching suppliers or transport modes in the case of supplier or transporter failure (Stecke & Kumar 2009), emergency deliveries (Inman & Blumenfeld 2013) postponement, multiple purpose resources (Hopp 2008) or flexible manufacturing systems (Gunasekaran et al. 2001)

While the first idea requires the high investment costs and tie capital into inventory, the second idea requires collaborative efforts to ensure fast recovery, information exchange (Bode et al. 2011) and it is more difficult to implement. Both approaches contain reactive redesign strategies, which are found more often in the relatively low predictability environments (Ketokivi 2006).

2.2 Contextual factors - Contingency theory lens

Contingency theory considers contingencies, i.e., contextual (or contingency) variables, response variables and performance variables. Sousa & Voss (2008, p.703) define *contextual variables* as “situational characteristics usually exogenous to the focal organization or manager”, *response variables* as “the organizational or managerial actions taken in response to current or anticipated contingency factors” and *performance variables* as the dependent measures which represent “specific aspect of effectiveness that are appropriate to evaluate the fit between contextual variables and response variables for the situation under consideration”. Similar to Blome et al. (2014) we consider product and supply business environment as contextual factors that shape the effects of the redesign strategies on the supply chain scenario.

Product characteristics. Product characteristics represent properties of raw materials or final products (Kirezieva et al. 2013) and we present characteristics reported in the literature. *Longevity and physical characteristics* of products indicate a complexity of its production and requirements for logistics processes in terms of packaging needs, storage conditions, material handling and warranty date and conditions. Generally, more fragile products, susceptible to environmental influences and less durable, the higher chance for product damage and disposal cost is. *Product assortment* represent external variety (Pil & Holweg 2004), i.e., a number of different stock keeping units or end-product configurations available to customers. Increased product assortment is typically consequence of variety in packaging sizes, labels and brands (Van Donk 2001). Though large product assortment results in increased inventory costs (Closs et al. 2010), it enables product substitution to avoid situations of inventory shortage, obsolescence and low customer service. *Product customization* might occur in any point of a supply chain and it requires certain type of processing, ranging from simple operations such as cutting or mixing to more complex operations that require specialized resources. (Olhager 2003) states that product customization might affect supply chain scenario as well. Both product assortment and customization have been identified as a means to achieve a competitive advantage (Scavarda et al. 2010). *The number of components* needed to build a product is strongly related to the number of production steps, which affects production complexity (Inman & Blumenfeld 2013) and indicates the type of a network structure. Inman and Blumenfeld found that the higher the number of parts, the higher the risk of a missing part is and the higher the risk of disturbance in production is.

Based on Blome et al. (2014), identified product characteristics indicate *product complexity.* Similar to Ketokivi (2006), they considered that the higher the customization, the number of components and assortment, the higher the complexity is. Though product complexity might affect effectiveness of redesign strategies on the supply chain scenario (Eckstein et al. 2015), it is rarely considered in relation to vulnerability, robustness and resilience of supply chains (Inman & Blumenfeld 2013).

Business environment. Business environments consider the supply and demand conditions. In this paper, we focus on supply conditions and its relevant characteristics. *Market capacity risk* occurs when there are only a few supply sources available (Zsidisin 2003), which exposes supply chains to a product shortage. This is especially the case of strong competition, when suppliers may switch customers. *Geographical dispersion* of suppliers (Brandon-Jones et al. 2015) might contribute to higher risks of disturbances, as internationally located suppliers require long shipping lead times due to border crossings, consolidation/deconsolidation centers and mode changes (Inman & Blumenfeld 2013). Inman and Blumenfeld highlight that these environmental factors increase not only the probability of a disturbance, but also its impact. *Uncertainty in supply* occurs due to unexpected events that affect timing, quantity or quality of inputs, such as delays due to traffic accidents, supplier's failure or mistakes in order picking (Vlajic et al. 2013). As such, it affects inventory or supplier management procedures. Changes in domestic or international trading *regulations* can open or restrict sourcing possibilities, thus influencing efficiency of purchasing function, as well as supply chain and logistics operations. Moreover, regulations can impose the form of information exchange and communication between supply chain partners. For example, information exchange with suppliers can take the form of non-structured and structured communication. In make-to-order systems non-structured communication improves supply chain performances, while structured communication increase costs in a situation of a high supply complexity (Gimenez et al. 2012).

Based on (Gimenez et al. 2012) and related studies, identified characteristics of business environment indicate *supply complexity,* which may impact effectiveness of redesign strategies applied on the supply chain scenario. The literature suggests that the higher marker capacity risk, larger geographical dispersion of suppliers, higher uncertainty in supply and frequent changes of regulations contribute to higher complexity of the supply chains. Similar to (van Donk & van der Vaart 2004) who found that higher supply complexity results in higher integration of the supply chain and improvement of performances, we propose that a higher complexity in supply implies an increased effectiveness of redesign strategies applied to the supply chain scenario.

3. METHODOLOGY

Objective of this study is to investigate *how* contextual factors such as product and environment characteristics affect management of supply chain vulnerabilities, i.e. the effectiveness of redesign strategies to change the supply chain scenario.

'*How*' type questions are best answered by using a case study methodology (Yin 1994). As Eisenhardt (1989) and (Meredith 1998) advise, case selection should be based on theoretical sampling. Furthermore, to build a theory from case studies, researchers should collect specific data in a systematic manner (Mintzberg 1979). In this case, such data must refer to the supply chain scenario characteristics, product and business environment characteristics that would provide insights into the disturbances and resulting vulnerability of a supply chains, as well as redesign strategies to manage the vulnerability.

The literature calls for research on real supply chain disturbances, and supply and product complexity (Inman & Blumenfeld 2013). Thus, for the purpose of this study, we select a supply chain of a large retailer, perishable products and a business environment of a developing country for the following reasons:

- Large retailers typically source wide assortment of products, have complex supply chain structure, and they are in position to manage entire supply chains (Coe & Hess 2005).
- Fresh food is a challenging part of the retailers' assortment which might result in food loss and waste (Papadima & Bloukas 1999), loss of profit and loss of reputation. On the other hand, fresh food products can be customized (i.e.

processed) in relation to the size of product, weight, color, production type (e.g. organic or not) at the producer as well as in the retail outlets.

- Developing countries face multiple challenges that result from issues related to the infrastructure, institutional control, and trade (Vlajic 2015), and successful retailers must redesign their supply chains on a continuous basis to manage vulnerabilities.

3. EXPECTED FINDINGS AND CONCLUSION

The supply chain and operations management literatures suggest that supply chain designs are shaped by contextual factors, i.e. high-inertia contextual variables. In most cases these variables are possible to change only in the long term and with the substantial effort (Sousa & Voss 2008). However, there is a scarce literature that provides more insights how these contextual factors shape effectiveness of redesign strategies when applied to supply chains to manage their vulnerability. In particular, product complexity is not much studied in connection to supply chain vulnerability (Inman & Blumenfeld 2013), nor how to manage vulnerability. Though there are studies that analyze impact of supply complexity on supply chain integration (Gimenez et al. 2012; van Donk & van der Vaart 2004) or flexibility (Blome et al. 2014), only Brandon-Jones et al. (2014) explained how supply chain complexity factors affects redesign strategies aimed to increase robustness and resilience.

In this study, we propose the use of a case study methodology to test propositions that result from this literature review and contingency theory:

P1: Product complexity affects the effectiveness of redesign strategies to manage supply chain vulnerability by preventing or mitigating disturbances in supply chain processes.

P2: Supply (business) environment complexity affects effectiveness of redesign strategies to manage supply chain vulnerability by preventing or mitigating disturbances in supply chain processes.

Furthermore, more detailed research is needed to investigate:

- does the disturbance prevention or mitigation related strategies are more used in the case of high product complexity and/or high supply complexity;
- how specific product or supply environment related factors affect link between each redesign strategies and supply chain vulnerability.

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END-OF-LIFE VEHICLE MANAGEMENT: A SURVEY OF LOGISTICS NETWORK DESIGN MODELS

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Abstract: *End-of-life vehicles are classified as hazardous waste and may cause serious environmental pollution and transportation safety problems with improper management. The end-of-life vehicle management is of vital importance for environment conservation, circular economy and sustainable development. This process is not only profit-oriented, but also dependent on legislations and aimed at reducing health hazards. This paper investigates the current research within the area of end-of-life vehicle management through a brief survey of logistics network design models. The purpose of this paper is to provide a content analysis overview of exclusively peer-reviewed international journal papers published in the period 2013-2019. The distribution list is created to identify primary publication outlets. Finally, on the basis of the performed review, several important avenues for future research are highlighted. This review could provide a source of references for researchers interested toward the optimization modeling of green logistics systems and inspire their additional attention.*

Keywords: *End-of-life vehicle, Network design, Logistics, Content analysis.*

1. INTRODUCTION

End-of-life vehicles (ELVs) are classified as hazardous waste and have the potential for polluting the environment if they are not managed properly (Simic, 2016). ELVs are the single largest hazardous waste category from households (Raja Mamat et al., 2018). They represent a category of waste whose processing is especially difficult because of their complex structure and varied composition. ELVs also contain important renewable resources which are considered as urban minerals. As the number of ELVs is estimated to increase to approximately 80 million units per year by 2020 (WRME, 2014), there is strong motivation to effectively manage this fast-growing waste flow.

ELV management is of vital importance for environment conservation, circular economy and sustainable development. This process is not only profit-oriented. The management of ELVs is significantly dependent on legislations, like Directive 2000/53/EC (EU, 2000) in the European Union, Law on recycling of ELVs (MOE, 2002) in Japan, Technical policy

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for the recovery and utilization of automobile products (NDRC, 2006) in China, Act on the resource circulation of electrical and electronic equipment and vehicles (ME, 2010) in Korea, etc. Sound management of ELVs has become the principal sustainability issue in most countries worldwide and therefore requires sophisticated decision-making tools for optimizing its efficiency (Simic and Dimitrijevic, 2015).

Today, the ELV management is a well positioned and emergent research area. Recently, several review papers have been published (Table 1). Simic (2013) reviewed the environmental engineering issues of the ELV recycling by covering a wide range of peer-reviewed journal papers published in the period 2003–2012. A review of the literature published in year 2012 on topics relating to automotive wastes is presented in Kindzierski et al. (2013). Lashlem et al. (2013) presented a brief review of ELV management practices world-wide. Li et al. (2014) provided an overview of present ELV management practices in China. Guigard et al. (2014) presented a review of the literature published in year 2013 on topics relating to automotive wastes. Topics include solid wastes from autobodies and tires, and vehicle emissions to soil. Sakai et al. (2014) provided a comparative analysis of ELV management practices in several countries. Cossu and Lai (2015) presented a general overview of post shredder technologies for treatment of ASR. Cucchiella et al. (2016) provided a mini-review on the automotive electronics recycling topic in the period 2000-2014.

Table 1. Summary of recent review papers

References	Topic	Analysed period
Kindzierski et al., 2013	Automotive waste	2012
Guigard et al., 2014		2013
Cossu and Lai, 2015	Automotive shredder residue treatment	2005-2014
Simic, 2013	Environmental engineering issues	2003-2012
Lashlem et at., 2013	Management practices	-2012
Sakai et al., 2014		-2012
Li et al., 2014		2005-2012
Cucchiella et al., 2016	Automotive electronics recycling	2000-2014

The most recent and relevant review papers are limited to some specific area of ELV management. Moreover, a holistic view of state–of–the–art logistics network design models is still missing from the available reviews. Hence, additional research effort to address this important topic is needed.

This paper investigates the current research within the area of ELV management through a survey of logistics network design models. The purpose of this paper is to provide an extensive content analysis overview of exclusively peer-reviewed international journal papers published in the period 2013-2019. Grey literature is excluded from this review.

All collected original research papers are analyzed and classified based on their modeling technique, solution approach and type of supply chain. Finally, the distribution list is created to identify primary publication outlets.

The remaining part of the paper is organized as follows: Section 2 provides a review methodology. Section 3 presents the obtained results of the review. The last section presents the paper's main conclusions and recommendations.

2. METHODOLOGY

In this paper, content analysis method is adopted for literature review. Content analysis is an observational research method that is used to systematically evaluate the symbolic content of all forms of recorded communication and also helps to identify the literature in terms of various categories (Pokharel and Mutha, 2009).

Search engines were used to explore ACS Publications, ASCE Library, ASME Digital Library, Cambridge JOURNALS, EBSCOhost, EmeraldInsight, Google Scholar, IEEE Xplore, Inderscience, IntegraConnect, IOPScience, J-STAGE, JSTOR, ProQuest, RSCPublishing, SAGE journals, ScienceDirect, SciVerse, SpringerLink, and WILEY databases for literature. In addition, the references cited in each relevant literature were examined to find out additional sources of information.

3. RESULTS

Farel et al. (2013) used a mixed integer linear programming modeling technique to determine the optimal topology and material flows in future ELV glazing recycling network. Gołębiewski et al. (2013) proposed a simulation approach that could be used to determine optimum locations for dismantling facilities in Poland. Mahmoudzadeh et al. (2013) used a mixed integer linear programming formulation to solve the location-allocation problem of ELVs scrap yards in Iran. Merkisz-Guranowska (2013) proposed a bi-objective mixed integer linear programming model aiming at the reorganization and construction of the ELV recycling network in Poland.

Mora et al. (2014) proposed a mixed integer linear programming model for ELV closed-loop network design. Ene and Öztürk (2015) formulated a mixed integer linear programming model for managing reverse flows of ELVs within the framework of a multi-period, multi-stage, capacity-constrained network design problem.

Chen et al. (2016) investigated coordination in the green supply chain and applied cooperative game theory to analyze economic benefits of two different pricing strategies. Demirel et al. (2016) proposed a mixed integer linear programming model for reverse logistics network design including different actors taking part in ELV recycling system.

Balcı and Ayvaz (2017) provided a mixed integer linear programming model to design ELV recycling network in Istanbul, Turkey. Özceylan et al. (2017) presented a mixed integer linear programming model to optimize a closed-loop supply chain for ELV treatment in Turkey. Phuc et al. (2017) formulated a fuzzy mixed integer linear programming model for designing multi-echelon, multi-product reverse logistic network. The economic parameters and ELV supply were considered as fuzzy values.

Lin et al. (2018) proposed a mixed integer linear programming model for the facility location-allocation problem of ELV recovery network. An improved artificial bee colony metaheuristics was applied to solve the model. Shankar et al. (2018) formulated a mixed integer linear programming model to meet the requirements of the strategic closed-loop supply chain network design in the context of India. A cooperative game was played to compute the best possible combination of strategies. Sun et al. (2018) developed a mixed-integer bilevel linear programming model to locate distribution centers for collecting parts of ELVs. The outer and inner optimization tasks were minimizing location costs and transportation cost respectively. Yildizbaşi et al. (2018) proposed a fuzzy mixed integer linear programming model to optimize the production and distribution planning for a closed-loop supply chain network inspired by the Turkish automotive industry. The authors used four different interactive fuzzy programming approaches to tackle the trade-offs among three objective functions.

Kuşakcı et al. (2019) modeled the problem of designing ELV reverse logistic network for Istanbul Metropolitan area as a fuzzy mixed integer linear program. The authors assumed that ELV supply could be presented as a fuzzy parameter. Xiao et al. (2019) developed a mixed integer linear programming model for constructing a four-tier reverse logistics network model, which includes ELV sources, collection centers, remanufacturing centers and dismantlers.

As a first step, all collected original research papers are classified based on their modeling technique (Table 2). The reviewed papers are classified into three categories: (1) mathematical programming, (2) simulation and (3) game theory. For the sake of clarity, the first category is further divided into four sub-categories: (1) mixed integer linear programming, (2) fuzzy mixed integer linear programming, (3) bi-objective mixed integer linear programming and (4) mixed integer bilevel linear programming. The mathematical programming is by far the most popular modeling technique. Also, ten papers (58.8%) utilized the mixed integer linear programming as modeling technique for designing logistics network for ELVs.

In the second step, reviewed research papers are classified based on solution approach in three categories (Table 2): (1) exact, (2) heuristic and (3) meta-heuristic. Almost all researchers (88.2%) solved logistics network design problems with exact methods, mostly applying solvers like Lingo, GAMS or CPLEX.

Afterward, the surveyed research papers are classified based on supply chain type in two following categories (Table 2): (1) open loop and (2) closed-loop supply chains. The analysis showed that traditional and novel closed-loop supply chain design, which simultaneously considers forward and reverse supply chains, have attracted almost equal attention among researchers.

Finally, the distribution list of peer-reviewed international journal papers published in the period 2013-2019 is created in Table 3. From the distribution list of journal papers (Table 3) it can be concluded that the primary publication outlets for the highlighted research area of ELV management are: Journal of Cleaner Production (23.5% share), Computers and Industrial Engineering (17.6% share) and Resources, Conservation and Recycling (11.8% share), jointly publishing 52.9% of the total number of identified peer-reviewed international journal papers printed in the period 2013-2019.

Table 2. Classification of logistics network design models by modeling technique, solution approach and type of supply chain

References	Modeling technique		Solution approach	Supply chain
Farel et al., 2013	Mathematical programming	Mixed integer linear programming	Exact	Open loop
Mahmoudzadeh et al., 2013			Exact	Closed-loop
Mora et al., 2014			Exact	Closed-loop
Ene and Öztürk, 2015			Exact	Open loop
Demirel et al., 2016			Exact	Open loop
Balcı and Ayvaz, 2017			Exact	Closed-loop
Özceylan et al., 2017			Exact	Closed-loop
Lin et al., 2018			Meta-heuristic	Open loop
Shankar et al., 2018			Exact	Closed-loop
Xiao et al., 2019			Exact	Open loop
Phuc et al., 2017		Fuzzy mixed integer linear programming	Exact	Closed-loop
Yildizbaşi et al., 2018			Exact	Closed-loop
Kuşakcı et al., 2019			Exact	Open loop
Merkisz-Guranowska, 2013		Bi-objective mixed integer LP	Exact	Open loop
Sun et al., 2018		Mixed integer bilevel linear programming	Exact	Open loop
Gołębiewski et al., 2013	Simulation		Heuristic	Open loop
Chen et al., 2016	Game theory		Exact	Closed-loop
Shankar et al., 2018			Exact	Closed-loop

Table 3. Distribution of journal papers published in the period 2013-2019.

Journal	Year of publication							Share [%]	Total
	2013	2014	2015	2016	2017	2018	2019		
Journal of Cleaner Production	1	–	–	1	–	1	1	23.5	4
Computers and Industrial Engineering	–	–	–	–	2	–	1	17.6	3
Resources, Conservation and Recycling	2	–	–	–	–	–	–	11.8	2
Others (8 journals)	1	1	1	1	1	3	–	47.1	8
Total (11 journals)	4	1	1	2	3	4	2	100	17

Note: Others (8 journals): Waste Management; International Journal of Production Economics; Journal of Sustainable Development and Planning; International Journal of Logistics Systems and Management; International Journal of Material Science; Southeast Europe Journal of Soft Computing; Simulation; Technological and Economic Development of Economy.

4. CONCLUSION

This paper investigates the research within the area of ELV management through a brief survey of logistics network design models proposed from 2013 to 2019. The review has showed that the most widely used modeling technique in the investigated period is the mixed integer linear programming. Exact solution methods are mostly provided. However, vast majority of surveyed logistics network design models were illustrated on either small or medium size cases studies or numerical examples. It should be outlined that when solving real-life large-scale problems this solution approach is significantly limited due to thousands of integer variables. It is found that Journal of Cleaner Production, Computers and Industrial Engineering and Resources, Conservation and Recycling represent primary publication outlets for the investigated research area.

According to the literature review of logistics network design models for ELV management, the following gaps and potential research fields for their improvements are noticed:

- Resource scarcity and volatile quantities of ELVs introduce risk in management systems. The available models can hardly provide network designs appealing to risk-averse waste managers. In fact, they can generate less reliable and inferior solutions. Thus, risk measurement methods integration into future optimization frameworks is one of possible improvements;
- Uncertainty is the key factor influencing the management of ELVs. However, uncertainty analysis is mainly ignored in the latest logistics network design models. Uncertainty analysis methods incorporated into future modeling frameworks could help avoiding erroneous strategic decisions;
- Researches of environmental and social consequences of introducing or extending ELV logistics network are also missing.

This review could provide a source of references for researchers interested toward the optimization modeling of green logistics systems and inspire their additional attention.

ACKNOWLEDGMENT

This work was partially supported by Ministry of Education, Science and Technological Development of the Republic of Serbia through the project TR 36006 for the period 2011–2019.

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WALKABILITY AND USABILITY OF STREET AFTER RECONSTRUCTION – POTENTIALS FOR REVERSE LOGISTICS

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Abstract: *This paper considers the relationship between Walkability and Usability in order to understand the perceptions of residents' accessibility to community facilities provided after the street reconstruction. To address this goal the assessment framework that includes two corresponding measurement tools has been proposed. The results show that the certain level of walkability has been achieved by the street reconstruction. However, the relationship of usability score with some of the walkability dimensions shows that land mix accessibility is not at the satisfactory level indicating the necessity for the intervention within the examined City area, in terms of the street facilities service efficiency transformation to enhance overall sustainability.*

Keywords: *neighborhood walkability, system usability, street reconstruction, perception.*

1. INTRODUCTION

The road infrastructure of a country not only serves the basic need for safe transport of people and goods but is also considered vital for its growth and development. Urban freight transport, and particularly solid waste and recyclables collection systems are largely influenced by the distribution of land use and associated activity patterns. These, despite the advancement of technology or the provision of infrastructure create logistical challenges that will need both economically feasible and environmentally sustainable solutions.

As a peculiar form of mobility, walking rely on dedicated infrastructure but is also highly dependent on the built environment (Krizek et al. 2009). Lamíquiz and López-Domínguez (2015) showed that land use factors were more relevant than urban design in determining people's modal choice. Others found that what they call micro-design variables such as block size or intersection configuration exert an influence on walking (Cervero and Duncan, 2003; Frank et al. 2007; Lamíquiz and López-Domínguez, 2015). However, some studies (Hillier and Iida, 2005) show that there is a close relationship between the configuration and the residents' perception and movement through urban

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space. The imperative is to integrate this kind of locally perceived qualities in citywide models (Cervero and Duncan, 2003; Giuliano and Narayan, 2003).

2. METHODS

2.1 The walkability assessment framework

The objective of this paper is to understand the perceptions of residents' accessibility to community facilities provided after the street reconstruction, and therefore it can be used as a framework for determining effects on different logistics activities, particularly those related to solid waste and recyclables disposal. According to Abley (2005) walkability can be defined as the extent to which the built environment is friendly to the presence of people living, shopping, visiting, enjoying or spending time in an area. Frank et al. (2006) claims that walkability is also dependent on human behavior (of the residents) in the neighborhood area. Many different methodologies have emerged from various fields of study (public health, social sciences, transport engineering, urban planning and architecture) to measure the built environment quality and urban walkability. Moura et al. (2017) states that tools and methods have been put forward including audit tools, checklists, inventories, level-of-service scales, surveys, questionnaires and indices. All of them were developed and applied, with the objective of guiding user's audits for integration in general master and transportation plans.

The present study was undertaken to better understand the importance of perceived neighborhood walkability and possible environmental determinants of the street usability after reconstruction, as well as, to examine the shape and strength of the relationship of several built-environment attributes and street usability. Although the attributes used in study are not directly related to reverse logistics collection facilities, the idea itself can be used as kind of instruction to analysis the influence of distance on the motivation for recyclables disposal (González-Torre and Adenso-Díaz, 2005).

2.2 Street characteristics

Vojvode Stepe Street is one of the five most important roads in the territory of the city municipality of Voždovac. With a length of about 8 km it belongs to the longest city roads. This route, with 23 crossings, is slightly curved with correct visual perception possibilities in the most parts of the trace. Urban growth of the street surrounding demanded severe reconstruction of the street infrastructure and design in order to get fluent life of its users, and to establish good foundations for filling in empty spaces with new appropriate facilities. Concerning its high traffic frequency and concentration of various urban contents, and accordingly its functional complexity (Figure 1) specific design requirements/tasks were set. The aim of the project of street reconstruction was the adoption of the decision on the potential dislocation of tram tracks and realization of a certain street profile (Krstić and Žegarac, 2013). The street layout before and after reconstruction is presented in Figure 2.

Figure 1. Vojvode Stepe Street network and land use

Figure 2. The appearance of the road before and after reconstruction

2.3 Participants

A group of volunteers aged between 20 and 30 years was recruited from the students attending the Faculty of Transport and Traffic Engineering in Belgrade. All participants have inhabited at different locations along the street examined. The sample respondents were queried about their perceptions or awareness of environmental factors near their residence or in their neighborhood.

2.4 Data collection instruments

Neighborhood Environment Walkability Scale (NEWS)

The Neighborhood Environment Walkability Scale (NEWS) is one of several recently developed questionnaires designed to measure residents' perceptions of the environmental attributes of their local area. It aimed to capture constructs from transportation and urban planning literatures related to physical activity, mostly for transportation purposes (Saelens et al., 2003). NEWS is one of the most comprehensive and widely used self-report measures of the built environment, that assesses residents' perception of neighborhood design features including residential density, land use mix (covering both indices of proximity and accessibility), street connectivity, infrastructure for walking/cycling, neighborhood aesthetics, traffic and crime safety, and neighborhood satisfaction. Perceptions of neighborhood attributes were assessed among participants using slightly modified items from the NEWS scale in combination with items from the NEWS–A version of the NEWS (Cerin et al., 2006; Saelens et al., 2003). The Residential density subscale of the original NEWS and NEWS-A consists of six items rated on a 5-point scale (1 = none; 2 = a few; 3 = some; 4 = most; 5 = all). With the exception of the residential density and land use mix–diversity subscales, items from remaining NEWS sections scaled from 1 (strongly disagree) to 4 (strongly agree). Residential density items asked about the frequency of various types of neighborhood residences, from single-family detached homes to 13-story or higher apartments, and were weighted relative to the average density of single-family detached residences, so than weighted values were summed to create a residential density subscale score. The Land use mix – diversity subscale is assessed by the perceived walking proximity from home to 23 different types of destinations. Respondents were asked to provide their perception on how much time it would take to walk from home to reach these facilities. The amount of time was coded in 5min increments ranging from 1- to 5-minute walking distance (coded as 5) to ≥ 30-minute walking distance (coded as 1) indicative of low walkability. Higher scores on land use mix–diversity indicated closer average proximity. With the exception of the residential density subscale, all subscale scores were calculated as the mean across the subscale items (Cerin, et al., 2013). The final score on each dimension of the neighborhood environment was calculated based on the scoring method provided by (Saelens et al. 2003).

System Usability Scale (SUS)

System Usability Scale (SUS), developed by Brooke (1996) had a great success among usability practitioners since it is a quick and easy to use measure for collecting users' usability evaluation of a system. It consists of ten-item scale giving a global assessment of Usability, operatively defined as the subjective perception of interaction with a system (Brooke, 1996). To measure perceived street usability, SUS that provides a global view of usability based on subjective assessment was employed. The questionnaire is revised by experts with significant experiences in the related fields. SUS uses 5 point Likert scale to gather participant impressions of usability aspects. Respondents have to indicate the degree to which they agree or disagree with the statements. The selected statements actually cover a variety of aspects of system usability, such as the need for support, training, and complexity. Five out of ten statements were positive, while the other five statements were negative. In the aspect of system usability evaluation, the SUS is an efficient, time-conserving, and labor-saving way of subjective assessment. As a result, SUS will produce a single number representing a composite measure of the overall usability of the studied system. The overall SUS scores range from 0 to 100 in 2.5-point increments. The higher the score is, the more usable the system is and the more easily users can interact with it (Brooke, 1986; Isman & Isbulan, 2010).

2.5 Data analysis

Overall descriptive statistics (means, standard deviations, percentages, and distribution statistics) were computed for the sample on all measures. Bivariate correlation analysis was performed between the neighborhood-environment variables and overall SUS score. Data were coded, entered and checked using SPSS Version 21.

3. RESULTS AND DISSCUSSION

For each of the walkability components, mean scores were calculated for study participants. Residential density show high score values, which is not surprising taking into account that many new building are sprouting along the street. The highest mean scores were obtained for land use mix–diversity and land use mix–access subscales, indicating that residents perceive their neighborhood as high walkable. The lowest score of all received the aesthetics subscale. The mean score for crime was also very low which actually points to higher walkability. Respondents reported for poorer walking/cycling facilities which are the consequence of the lack of separate cycle lanes and inconsistent cycling infrastructure (Figure 3).

Neighborhood satisfaction mean score is 3.17. Students are most satisfied with the access to public transportation (M= 4.08) and commuting time to work/school (M= 3.95).

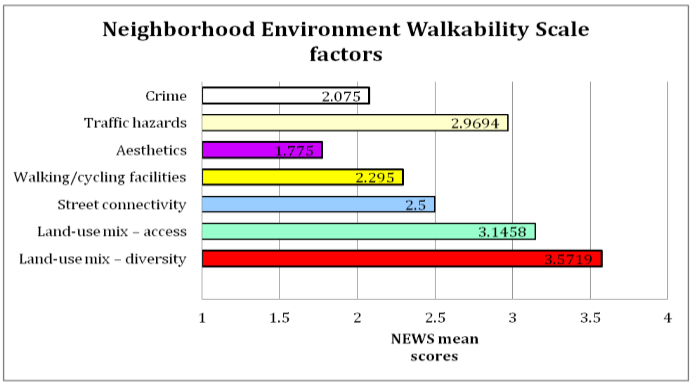

Figure 3. Subscale Scores from the Neighborhood Environment Walkability Scale

This can be explained by the fact that the majority of them live in the student dormitory located in the immediate vicinity of the public transport stop, or at a very short distance from the faculty so they can easily walk to a bus or tram station. The access to shopping opportunities and pleasantness of walking in the neighborhood were highly rated too (3.58 and 3.53, respectively). Their satisfaction with cycling facilities is very low (M= 2.25) which is in accordance with the low mean scores on walking/cycling subscale. Respondents are also annoyed by road-traffic noise as a characteristic of their residential milieu, since the dormitory, the faculty building or their residences are also located in proximity to tram tracks. The same participants evaluated the new street design using the System Usability Scale (SUS). The overall mean score of the SUS was found to be 54.125. The best way to interpret the SUS score is to convert it to a percentile rank. As SUS also enables a comparison of different systems, the interpretation should take into account that in studies that use the SUS to determine the usability of a system, an average score of 70 is generally awarded (Bangor et al. 2008). This means that a score of 66, for example, is considered more usable than 44% of the products in the (Sauro, 2011) database (and less usable than 56%). Anything with a percentile below 50% is, by definition, below average, and anything above 50% is above average. Low SUS scores indicate to the researchers and designers that they need to review the system and identify problems encountered with the design. Bivariate correlation analysis was performed between the neighborhood-environment variables and the overall street usability score (Table 1).

Table 1. Significant correlations between the NEWS factors and SUS overall score

		1	4	5	6	7	8	9
1	SUS overall score				-.328*	.460**	.318*	.613**
2	Residential density						.738**	
3	Land-use mix – access				.466**			
4	Walking/cycling facilities							.491**
5	Aesthetics	.499**	.459**		-.413**	.358*	.405**	.653**
6	Traffic hazards							
7	Crime							.376*
8	Land-use mix – diversity							.400*
9	overall satisfaction							

*. Correlation is significant at the 0.01 level (2-tailed).
**. Correlation is significant at the 0.001 level (2-tailed).

Overall satisfaction show statistically significant correlation to all other scales, excluding land use mix accessibility and traffic hazards. The largest correlations were found with aesthetics and overall SUS scores. Similarly, aesthetics subscale exhibited significant correlations to all other subscales, with the exception of residential density and land use mix accessibility. The strongest positive correlation was discovered between residential density and land use mix-diversity. Conversely, there were significant weak to moderate negative correlations between perceived traffic hazards and overall SUS score, as well as between perceived traffic hazards and aesthetics. The magnitude of our results is in line with previous studies (Leslie et al., 2005; Sallis et al., 1990). Nonetheless, if the street is perceived as less usable, there is a growing threat of traffic hazards. It may be that walkers in the present study may just be more aware of threats to safety, pay more attention and attach greater importance to traffic hazards due to their professional orientation. It is possible that traffic safety is a construct consisting of several dimensions, such as traffic volume, speed, and facilities for protecting and separating pedestrians and cyclists from traffic. Research needs to examine more specific aspects of traffic safety.

In assessment the influence of environmental factors, it is important to examine objectively observable domains such as distance to facilities (Sallis et al., 1990; Troped et al., 2001) and the location of participant's homes (Bauman et al., 1999). The findings may be, to a certain extent, attributed to a long-standing problem in the field, ''self-selection'' i.e., it is not the built environment that changes travel behavior, but values and attitudes of the people living in them. Namely, respondents in this study have chosen the place of residence with the intention to be as close as possible to the faculty. The perceived distance can be influenced by the type of land use and design characteristics. It was found that design element such as continuous walking systems that connect door fronts with transit stops or other destinations can create good connections (Rahman et al., 2018). The proximity of public transport and shopping spots make this street highly accessible for pedestrians. The importance of neighborhood buffer is relatively understudied and there is no consensus on what defines a 'neighborhood' (shape or size). Distances of 200m-1600m around participants' homes are typically used to represent the size of the neighborhood because these typically point at 'walkable' distances to local destinations (Jeffrey et al., 2019). All the aforementioned show how values, preferences and motivations mediate amongst the object and subject characteristics and provide powerful arguments to understand how individuals take modal choices. In the same time mentioned distances of 200m-1600m, which represent the size of neighborhood are also ideal for conducting analysis of motivation for recyclables disposal which need widening attribute sets.

Further, counter-intuitive associations were also found, e.g. lack of associations of street connectivity with other factors. The different direction for the neighborhood-based differences in aesthetics (residents of the low-walkable neighborhood had higher ratings of aesthetics) is likely to be attributable to the low-walkable area having topography with more trees, shrubs and open green spaces as well as scenic views, than did the high walkable area (Leslie et al., 2005). Cul-de-sacs may be an indicator of aesthetically pleasing environments, while areas with a grid street pattern may have more non-residential destinations that make walking more interesting. Well-connected street networks may facilitate residents' walking for transportation by providing direct and short routes to destinations (Berrigan et al. 2010). Perhaps, there are moderators of the aesthetics-walking association. Thus perceptions of aesthetics and safety could reflect real differences across objectively measured neighborhood types or differences in the way the perceived and objective built environment measures are operationalized (Jack and McCormack, 2014). Evidence show that configuration statistically determines how pedestrian flows are distributed within street networks, even without considering land uses (Lamíquiz and López-Domínguez, 2015).

McCormack and Shiell (2011) acknowledge that some environmental attributes could be located under multiple categories that may not be mutually exclusive. For example, connectivity, land use mix, and traffic-related factors are associated with walking for transport but not recreational walking, and population density is associated with walking but not cycling for any purpose. Perceived land use mix–access is significantly and positively associated with perceived street connectivity, whereas in the present study related to traffic hazards. Studies that have reported on intersection density (an objective measure of perceived street connectivity) indicated that intersection density was associated with walking for transport (Kerr et al., 2015). The high walkability neighborhood had a mixture of single- and multiple-family residences (which is consistent with higher residential density), a concentration of nonresidential land uses (restaurants, grocery or convenience stores, and other small retail stores) along the main corridor of the neighborhood, having a mostly grid like street pattern, with short block lengths and few cul-de-sacs (Saelens et al. 2003). Researchers in planning and transportation have identified land-use mix, residential density and street connectivity as the key aspects for creating walkability indices (Frank and Pivo, 1994). The lack of street connectivity associations with other walkability dimensions in the present study may be due to low perceived street usability (Čičević et al., 2017).

3.1 Limitations and further research

It should be recognized that the current study suffers from several limitations. Conceived as a pilot investigation, restricted to small sample in one neighborhood in one city means that comparisons should be considered preliminary. Neighborhood from which participants were recruited, may have limited variability of some of the environmental attributes and therefore increase the chance of finding atypical profiles of environmental indices. Further studies that involve comparisons across different contexts be necessary to understand the factors that influence the effect size of walkability. Further research using longitudinal data would be required to follow the impact of changes in neighborhood layout or design (improvements, reconstruction).

4. CONCLUSION

Neighborhood environmental quality is an important factor that affects human wellbeing, which, fortunately, can be improved through proper urban management. Many cities around the world are now developing integrated solutions to major environmental challenges and are transforming themselves into more sustainable and self-sufficient communities (Dizdaroglu et al., 2009). It has been clear that the pedestrian friendliness of urban environment is better described using no single but composite indices. Most of them aim to be operative tools to evaluate and design walkable communities (Southworth, 2005). They may be helpful to decision makers in where to focus transportation investments and where to guide future growth.

The project of street reconstruction is being delivered within the context of a highly urbanized setting where the optimum solution is derived from a balance of competing technical and stakeholder constraints. However, as Hildebrand (2003) claims, developing transport infrastructure only provides alternatives but does not necessarily change one's travel behavior. This implies that a people-centered approach is essential to understand how people actually behave in making (sustainable) travel choices. Within neighborhood walkability, besides *hard* factors (that can be quantified and measured - residential density and land use) contribution of household waste management parameters in the context of Reverse Logistics (RL) (Jalil et al. 2016; Purkayastha et al., 2015; Senawi and Sheau-Ting, 2016; Trabold and Babbitt, 2018) should be co-examined (accessibility, availability, convenience of waste bins, collection schedules, accessibility and route planning for waste collection vehicles, etc.). Thus, the recommendation is that NEWS scale should be extended by adding items (waste bins presence awareness, preferred and acceptable walking distances to bins, recycling knowledge and attitudes, etc.), which affect RL processes in certain urban area.

With better understanding and more consistent and frequent measurement of the walkability and usability of urban environments, by means of inexpensive, time-conserving and labor-saving instruments decision-makers will be empowered to enact policies that create more sustainable urban areas. The study results indicate a need for more definitive research regarding the relationship between the two very important constructs, neighborhood walkability and usability to prioritize neighborhood changes. Thus, these changes impose the necessity for the waste disposal facilities distance attributes assessment, in order to be improved by the RL practice.

ACKNOWLEDGMENT

This work is partially supported by the Ministry of the Science and Technological development of the Republic of Serbia under No. 36012, No. 36022 and No. 36006.

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Part V

WAREHOUSING AND INFORMATION TECHNOLOGIES IN LOGISTICS

PIECE PICKING TECHNOLOGY SELECTION

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Abstract: *Order picking is process that is realized in warehouses of unitize goods and includes all the activities that follows picking of demanded assortment of goods according to its kind and quantity in order to fulfill customers' demands. Order picking is known to be the most labor-intensive and also one of the most costly functions among all the warehouse functions. Depending on the types of retrieval units, types of order picking can be classified into pallet picking, case picking and piece (broken -case) picking. We focus our research on piece picking technologies. In order picking area piece order picking process could be realized on different and nowadays numerous technical solutions. During warehouse design process, selection and involvement those technologies for defined requirements, limits and functions is hard task. In this paper one approach of solving this problem is presented.*

Keywords: *piece picking, order picking, warehouse*

1. INTRODUCTION

Order picking (OP) is process that is realized in warehouses of unitize goods and includes all the activities that follows picking of demanded assortment of goods according to its kind and quantity in order to fulfill customers' demands. OP is known to be the most labor-intensive and also one of the most costly functions among all the warehouse functions. Depending on the types of retrieval units, OP can be classified into tree basic categories [Park (2012)]): (i) pallet picking, (ii) case picking and (iii) piece picking (Figure 1.1).

- (i) Pallet picking is present when the order concerns on homogenous pallet units picking;
- (ii) Case picking is realized when ordered quantities is less then whole quantity in homogenous pallet unit (few case units). This process is typical when pallet with mixed content is needed;
- (iii) Piece picking (PP) is also known as 'broken-case picking' or 'split-case picking' and involves an picking order, where the picking quantity is less than a full case or is in pieces. Here individual items are picked from crates or open cartons. On this occasion, dispatch units are formed, usually in the form of mixed cases. PP is

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characterized with large number of item types, small quantities per pick, and short cycle times.

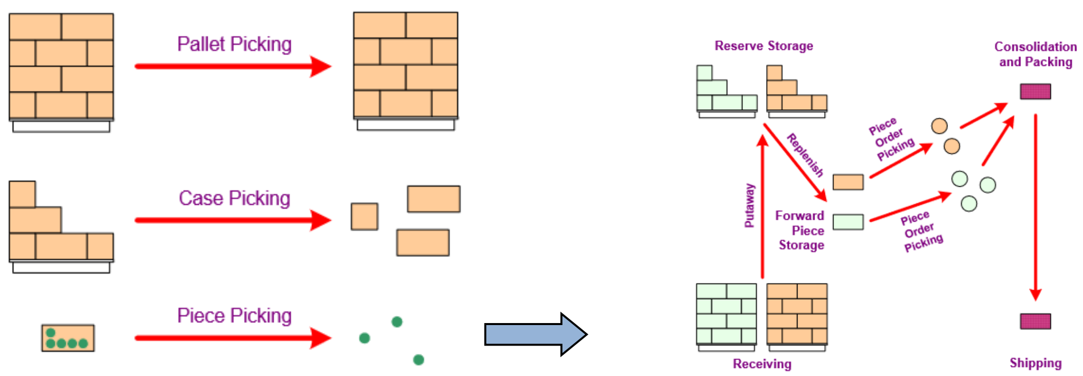


Figure 1.1. Trees basic categories of OP [Kay (2009)]

The picking operation has changed significantly over the past 20 years [Gwynne (2014)]. Nowadays present approaches (Just-in-time methods, increasing internet sales and initiatives such as efficient consumer response (ECR) and quick response (QR)) are resulting in smaller, more frequent orders. This again necessitates changes in warehouse operations, with a move away from full-pallet picking to case picking and PP. PP form of OP will be more dominant type of logistics activities in the future. All mentioned resulting that PP is the most complicated, costly, and most effort-intensive types of Order Picking System (OPS).

The designers of OPS therefore face great challenges, including: increasing labor costs, less available space and more frequent small orders with shorter delivery times. Consequently, there are constant research efforts devoted to new innovations that aim to reduce operational costs, generate higher productivity, optimize the space utilization rate and enhance service levels. Multiple and complicated requirements results that a lot of handling/equipment types are developed and present in technologies of PP processes.

OP technologies that could be applied in order picking area (OPA) are different and they are more numerous as the time passing by. During designing warehouse/OPA always is present dilemma which technology should be applied in real circumstances. Generally, problem of defining alternative technologies and decision which one to be selected is one of the hardest tasks during design process. This paper is focused on this problem and offers one possible approach to solve them.

The remainder of this paper is organized as follows. In chapter 2 some of basic alternative PP technologies are presented and classified. In chapter 3 one practical approach for generating and selection of technological conceptions piece picking (TCPP), with examples, is presented. Finally, in chapter 4 we conclude the paper and discuss opportunities for future research.

2. PP TECHNOLOGIES

The consideration of the OP process technology realization relates to the character of interrelationship, on the one hand, of technological requirements as parts of OP task, and on the other hand, on technological system elements [Vukićević (1995)]. Having in mind a wide range of OP tasks, an even greater set of OP solutions has been developed, based on the application of different technological elements - technologies for the realization of certain technological requirements in the OP process. They are characterized by different combinations of storage, handling, and transport technologies with different automation levels of these processes. Accordingly, it is possible from the technological aspect to apply the classification of piece picking system (PPS) to different criteria.

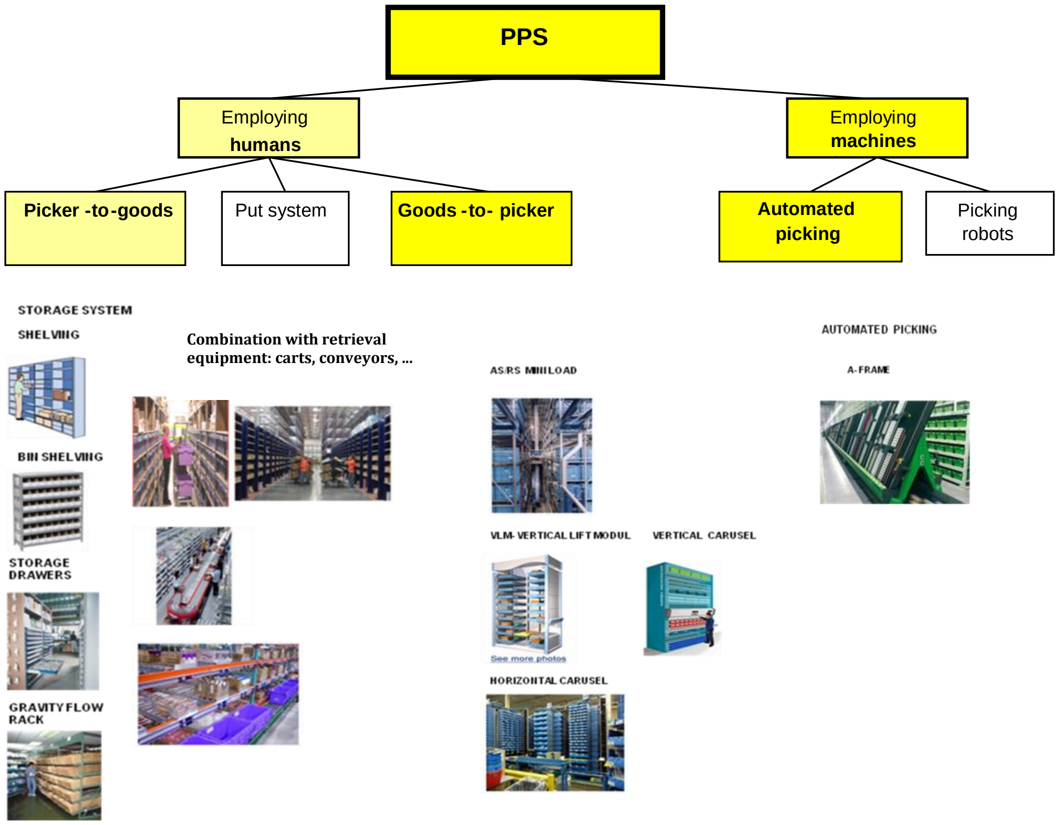


Figure 2.1. Classification of PPS (based on [de Koster et al. (2007)).

Technologies shown on the Figure 2.1 distinguishes PPS according to whether humans or automated machines are used [de Koster et al. (2007)]. The most of warehouses engage humans for OP. Among these, the *picker-to-goods* (PTG), where the order picker walks or drives to storage location to retrieve/pick items is typical. In PTG systems most popular storage equipment are: shelving, bin shelving, storage drawers and gravity flow rack. This equipment in typical technologies is often combined in various variants with retrieval equipments: picking carts, picking conveyors and order picker truck. In typical *goods-to-picker* (GTP) systems, the container or the storage location housing requested item is mechanically brought to the picker for retrieval. In GTP systems the retrieval equipments are typically integrated with storage equipments to become an automated storage/retrieval system. Consequently, usual GTP systems act as a modular subsystem of the whole warehouse system. In GTP systems, three popular storage/retrieval systems are: carousel systems, miniload systems, and vertical lift modul –VLM. An A-frame dispenser system is an *automated PPS* used for high-speed, high throughput OP of small and well packaged individual items with uniform size and shape. It consists of a set of dispensers in two rows configured as an A-frame. Typically, a conveyor runs through under the A-frame.

These various technologies suitable for different PP range from labor-intensive to highly automated. Each technology has its own set of advantages/disadvantages and compromises. They need to be analyzed first of all in terms of typical application, benefits, compromises (including the amount of space/footprint it requires, how easily it can be expanded, and the levels of throughput, productivity, accuracy, inventory control and ergonomics it supports), and general cost information. As the available space is limited, here will not be presented a more detailed description of these technologies. A good overview of PP technology is given in the literature: Gwynne (2014), Vukićević (1995), Hompel et al.(2011) and Frazelle (2002).

3. TECHNOLOGY SELECTION PROBLEM

The choice of OP technology is one of the most important decisions in warehouse designing with far-reaching consequences for its functioning. The designer have to choose the technology that will fully meet the set of defined goals. Some of the objectives a designer is required to optimize include maximizing throughput or minimizing cost, space, response time, or error-rate, or a combination there of. Technology selection problem, in literature, generally is solved using multi-criteria decision models [Pazour and Meller (2014)]. Research on material handling technology selection are relatively rare and three major approaches are distinguished [Gu and McGinnis (2010)]: (i) general frameworks for technology selection that are based on empirical experiences (e.g. Yoon and Sharp (1996) and Chackelson et al.(2012)); (ii) mathematical models and algorithms that are limited to selecting transport technologies (e.g. Noble and Tanchoco(1993)); and (iii) knowledge-based rules (e.g. Noble and Tanchoco(1993a) and [Dallari et al. (2009)).

None of these approaches gives full support for generating and selecting PP technology. It could be seen that the generation of variants is cited as an art part of the design process [Apple et al. (2010)] and hence it is not appropriately treated. An approach has been given in this paper, adapted for practical problem solving for the generating and selection of PP technology in the design process. Here, it will be presented in his basic steps and aspects.

3.1 Generating and selection of acceptable alternatives

The TCPP is defined over three basic components material handling (MH) technology, picker guidance and method of OP (Figure 3.1). Each of these components appears in a large number of functional forms, but only their purposeful/suitable/harmonized combinations, due to the high degree of interdependence, are feasible alternatives. From this set of feasible alternatives one a set of acceptable alternatives is defined, between which the final solution is chosen. It is clear that this is a very important design work - a decision with a high influence on the future functioning of the system. The selected alternative (technology solution) largely defines some global parameters that have a decisive impact on the cost and performance of the OP/warehouse that will be monitored for many years-often throughout its lifetime. Below is a methodological approach-procedure for obtaining acceptable alternatives.

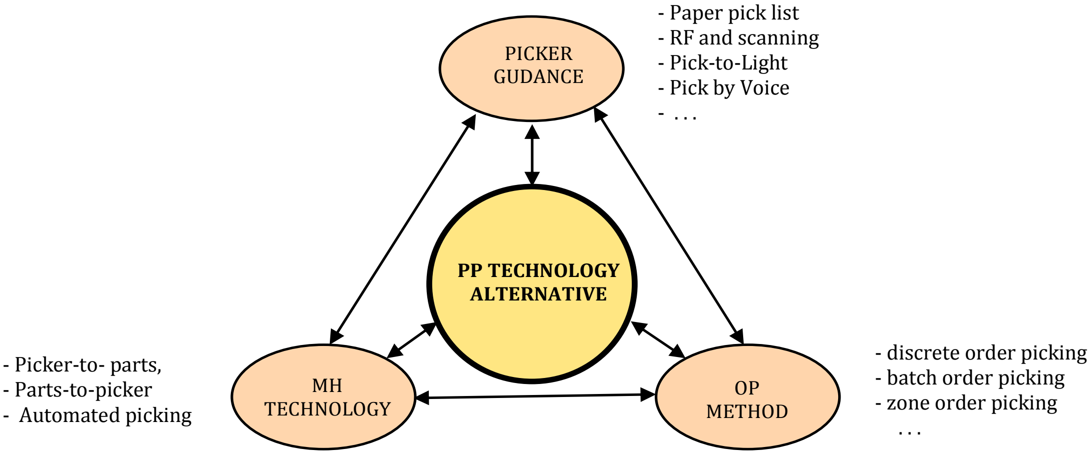


Figure 3.1. TCPP structure and interrelationship of basic components

3.2 Access to select alternative TCPP

Generating feasible TCPP alternatives is a creative act that involves knowledge of a large number of different variants of the partial components, their characteristics, as well as the possibility of combining them, or creating feasible alternative combinations. It could be described as a multiphase iterative process, where the basis of the solution - the concept - is chosen at the beginning, which is more precisely defined in each subsequent step of iteration, as the level of detail increases. In this way, there is a set of feasible alternative concepts, which number in some cases can be extremely large. This set of feasible variant concepts requires, for design purposes, the application of appropriate selection criteria to be reduced on 2-5 acceptable alternative concepts. Theoretically, it is necessary to carry out a two-step process which involves: (i) generating - developing feasible alternatives, and then (ii) applying the selection criteria to reduce this set to a set of acceptable alternatives. This approach requires significant time engagement so it is rarely applied in design practice. More often in practice, the choice of experience-based alternatives is applied when several types of alternatives (the most common ones applied in similar situations) are defined. This approach narrows the choice and carries the risk of omitting suitable alternatives from consideration. For these reasons, the approach is suggested to be faster than the theoretical and more effective in relation to practice.

The novelty of the proposed approach is to avoid the theoretical two-step approach (the first approach to the set of feasible and then the reduction to a set of acceptable alternatives) is avoided by introducing the selection criteria even in the process of generating alternatives, and in this way it allows shortening the time for determining acceptable alternatives.

In the shortest sense: in all phases of the process, those alternatives are chosen that correspond not only to the conditions of the task, but also to the relevant criteria (required performance and limitations). The choice of task parameters and the choice of relevant criteria have a particularly important place in this approach (more detailed in the examples in Chapter 3.3).

Setting and defining tasks in the general form, respecting all relevant parameters, their characteristics would not be a rational or convenient approach. A more favorable approach, from the aspect of designing and making certain project decisions, is the one that defines and adjusts the task in relation to the decisions that need to be taken. Selected parameters of the task and their characteristics direct the process of generating - the development of potential alternatives (Table 3.1), and at the same time the relevant criteria is included in this process and reduces the number of alternatives, which can sometimes be large, to a narrow set of acceptable alternatives (Figure 3.2).

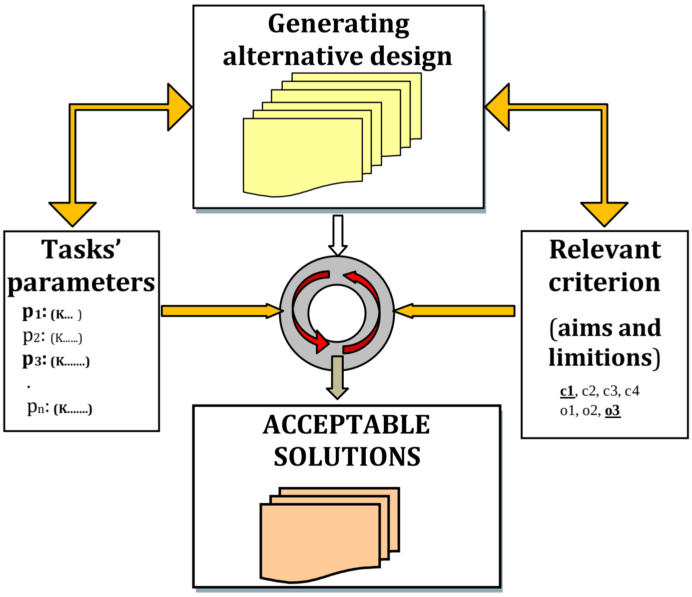


Figure 3.2 Relation of relevant factors of acceptable alternative selection

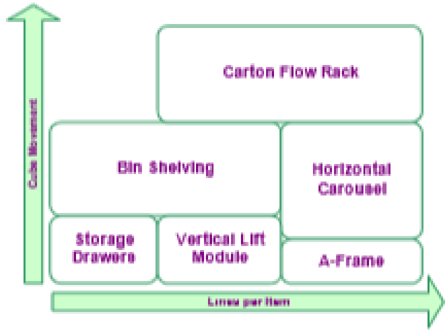
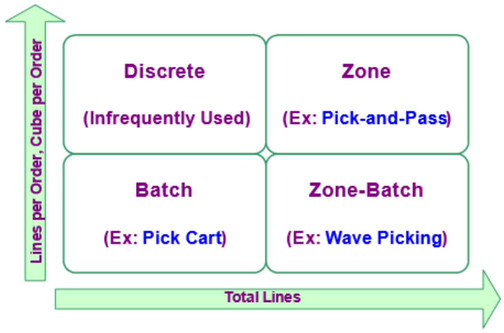
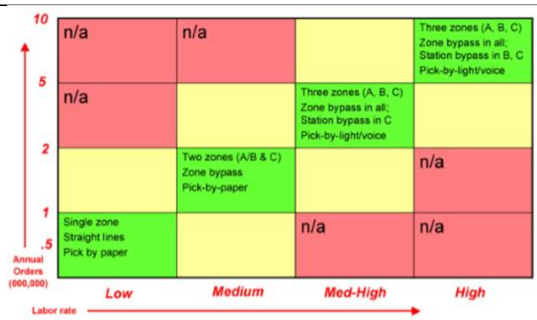
In this way, in all phases of the process of alternative generating, with the adjustment of the task (by selecting and introducing new parameters) and choosing the criteria, the selected acceptable alternatives from the previous phase are more closely defined to the final form. The time of favorable alternatives developing is significantly reduced, relative to the theoretical approach, for the purpose of reducing the search area and the necessary number of iterations. Alternatives selection and elimination processes are based on the application of logical and/or low-level quantitative analysis that allows the designer to decide in the early stages of generating alternatives whether any of them keep on into the analysis procedure or is rejected. A necessary assumption for their implementation and making valid decisions is the knowledge and/or assessment of the basic performance measures (eg: flow, service levels, costs, utilization rate, etc.) of individual alternatives.

Below are given recommendations for development and making decision on selection of variants TCPP. On one example, a selection of relevant task parameters was presented in the function of making certain decisions.

3.3 Recommendations for development and making decision on selection of TCPP

The recommendations for development and decision making on the selection of variants TCPP are demonstrated on one example. Selection of relevant task parameters was presented in the function of making certain decisions. In order to obtain relevant parameters / task information, it is necessary to carry out processing of data on goods, customer orders, system requirements and constrains using appropriate analytical procedures and methods [Frazelle (2002) and [Sharp et al. (2008)]. The obtained parameters and their quantitative characteristics (for different quantitative ranges), using the appropriate graphics, will serve as the basis for making certain project decisions (Table3.1).

Table 3.1- The selection of relevant task parameters in the function of making certain decisions [based on: Frazelle (2002) and Apple et al. (2010)]

What select_? (decision)	Relevant tasks parameters	Graphic
Appropriate type of ***MH technology***	***Cube Movement***—*the total unit demand of the item over some period of time times the cubic volume of each unit (representative of the cube in storage for the item);* ***Lines per Item*** *(a.k.a. popularity)—the total number of lines for the item in all orders over some period of time (representative of picking activity for item)*	
Appropriate ***OP method***	***Lines per Order***—*the average number of different items (i.e., lines or SKUs) in an order;* ***Cube per Order***—*the average total cubic volume of all of the units (i.e., pieces) in an order;* ***Total Lines***—*the total number of lines for all items in all orders over some period of time (representative of total picking activity);.*	
Appropriate **Picker guidance**	***Activity*** ***Labor Cost***	

Of course, they only allow for a coarse selection of technology, and for further steps in the process of generating alternatives it is necessary to include other auxiliary tools, e.g. matrix of compatibility. Compatibility matrices will allow you to identify the possibility of combining individual partial components into a feasible alternative. In addition, significant selection assistance provides information on the typical applications of particular alternatives (technologies, methods, etc.), their advantages and disadvantages. For example, for certain alternative technologies within the PTG system, the question of combining the storage and transport equipment, or the application of carts or conveyors, is raised. Defining the appropriate method is typically made based on the overall size of the OPA (travel requirements), throughput of goods (velocity) and pick density (e.g. in Table 3.2)

Table 3.2 Mode of Order Transportation [www.opsdesign.com]

	Commonly Used Operations	Benefits	"Draw Backs"
Pick to Cart	▪ Large number of items with low movement per item ▪ Full case and piece picks operations with little system support to split out the orders	▪ No conveyor cost ▪ Highly flexible ▪ Multiple pickers per zone, if required	▪ Low pick rate due to typically long travel paths
Pick to Conveyor	▪ Low number of items ▪ High volume items ▪ Large number of very small items (i.e. jewelry)	▪ High pick rate due to small pick zones	▪ Typically only one picker per zone ▪ Conveyor cost

Each of the alternatives is characterized by different potentials in terms of performance(s) (productivity, service level, flexibility, etc.), costs (different requirements in terms of resource recruitment (space, people, technology) and related investment and operational costs). In accordance with the methodology described in C hapter 3.2 it is necessary to include the selected relevant criteria in the selection of variants in all stages of the process. Criteria appear either as a goal or as a constraint. For example when they appear as a constraint, it is necessary to reach the target values without exceeding the given limits (e.g. the price of the system). As an example / help for roughly examining the performance of certain alternatives can be used by sources and data on productivity, initial costs, etc. (e.g. Table3.3 and Table 3.4).

Table 3.3 Summary Characteristics of Alternative PPS [Frazelle (2002)]

System Attribute	Unit of Measure	Bin Shelving	Gravity Flow Racks	Storage Drawers	Horizontal Carousel	Vertical Carousel	Miniload AS/RS	Automatic Dispersing
Gross system cost	Initial cost/ purchased Ft3	$5–15	$3–5	$25–30	$20–35	$40–70	$30–40	$300–600 per dispens
Net system cost	Initial cost/ available Ft3	$10–30	$9–15	$31–38	$40–70	$65–100	$38–50	
Floorspace requirements	Ft3 of inventory housed per Ft2 of floorspace	1–1.2	0.7–0.85	1.8–2.5	0.8–1.25	5.0–6.0	4.0–5.0	
Human factors	Ease of retrieval	Average	Average	Good	Average	Excellent	Excellent	Good
Maintenance requirements		Low	Low	Low	Medium	Medium	High	High
Item security		Average	Average	Excellent	Good	Excellent	Excellent	Average
Flexibility	Ease to reconfigure	High	High	High	Medium	Low	Low	Low
Pick rate	Order lines per person-hour	C: 25–125, T: 100–350, M: 25–250, W: 300–500	C: 25–125, T: 100–350, M: 25–250, W: 300–500	C: 25–125, T: 100–350, M: 25–250, W: 300–500	50–250	50–300	25–125	500–1,000
Key	T = Tote picking	C = Cart picking	M= Man-aboard ASRS	W= Wave picking				

Table3. 4… Key parameters for each pick technology types, including typical pick rates, low/medium/high ranges for SKUs, volume, order rates and product size, plus typical accuracy rates. [www.hksystems.com]

Attribute	Technology													
	Floor Shelving	"Man-up" VNA	Flow Rack	AS/RS (w/ Side Ports)	Horizontal Carousel	Vertical Carousel	Vertical Lift Module	AS/RS (End-of-aisle)	Case Sequencer	A-Frame	Robot	Tilt-Tray Sorter	Cross Belt Sorter	Dispensing System
Typical Pick Rate/Hr.	20-250	13-23	20-350	50-200	200-500	50-100	100-200	50-300	100-500	8,000-15,000	1,200-8,000	6,000-20,000	5,000-10,000	150-350
Number of SKUs	LM	L	LM	MH	LM	LM	MH	MH	LMH	LMH	LMH	H	MH	L
Cubic Volume	LM	LMH	LM	LM	MH	LM	LM	H	MH	L	LM	LMH	LM	M
Number of Orders	L	L	LM	LM	M	L	M	M	MH	H	MH	H	H	M
Item Size	LM	LMH	LM	LM	LM	L	LM	LM	LM	L	LM	LMH	LM	L
Accuracy (%)	90-95	90-95	99	99.9	99.9	99.9	99.9	99.9	99.99	95	100	99.8	99.5	100
Variable Unit Costs	$.07-1.25	$.87-1.92	$.06-1.25	$.07-.25	$.05-16	$.21-.56	$.10-.25	$.07-.50	$.01-.10	<$.01-.08	<$.01-.06	<$.01-.08	$.02-.10	<.$01-.06

LMH = low, medium, high

4. CONCLUSION

During designing a warehouse / OPS, the selection of technology is a significant and difficult task, especially expressed in the case of generating and selecting PP (probably one of the most complex tasks in the area of the warehouse design). In spite of its importance, this problem is not appropriately treated in the literature. Developed models and achieved results do not allow direct application and support in making project decisions that the practitioners / designers of these systems are involved. This paper represents an solution to correct this insufficiency in an appropriate way. The paper presents a methodological method adapted to practical problem solving generation and selection of acceptable variants. It enables the selection of the relevant project criteria in the process / process of generating alternatives (primarily guided by the parameters of the task and their characteristics) at the same time. In this way, quality and speed are ensured - the efficiency of the design process. The paper can be used as the basis for the development of a future ***decision support system*** (DSS) that would provide significant support in warehouse design processes.

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FOG COMPUTING IN LOGISTICS SYSTEMS

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Abstract: *The extension of cloud computing to the edge of the network through fog computing provides efficient resource utilization and higher performance regarding the delay, bandwidth and energy consumption. Fog computing is not a substitute for cloud computing. It enables data storage and processing at the edge of the network, with the possibility of interaction with the cloud data centers. Therefore, these technologies are adequate complements. Due to numerous advantages, fog computing is a promising technology for many applications, especially latency-sensitive applications requiring real-time processing. This paper analyzes the possibility of fog computing deployment in logistics systems. The benefits of fog computing deployment in an intelligent logistics center are observed. The architecture of a fog computing model in supply chain management is also addressed.*

Keywords: *fog computing, cloud computing, end devices, logistics systems*

1. INTRODUCTION

Computing paradigms have evolved from distributed, parallel and grid to cloud computing. Cloud computing provides scalability, on-demand physical and virtual resources allocation, reduced management efforts, flexible pricing and service provisioning. Virtualization, as a key cloud computing characteristic, can be defined as a set of techniques that abstracts the details of a physical element (e.g. hardware platform, storage device, operating system, or network resources) and provides virtualized resources. Due to virtualization, cloud resources can be provided in the form of virtual machines (VM). The virtual machine is a computing environment in which an operating system can be installed and run. Software execution on VMs is separated from the underlying hardware resources. Hence, VM emulates a physical computing environment that can be easily shared, copied or moved between host servers. The migration capability followed from virtualization enables on-demand resources allocation to applications. Furthermore, virtualization introduces elasticity, load balancing and economy of scale in the cloud environment. Due to numerous advantages, cloud computing has widespread use. However, there are some limitations. The major limitation is the connectivity between cloud and end devices, especially for latency-sensitive cloud-based applications,

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according to Mouradian et al. (2018). In addition, cloud-based applications are often distributed and consist of multiple components. Sometimes, application components are provided separately over multiple clouds, by Pop et al. (2016) and Martino (2014). Thus, the latency is increased due to the overhead introduced by inter-cloud communications. In addition, data processing might be necessary at locations where a cloud provider may have no data center.

Fog computing is a computing paradigm introduced as the extension of cloud computing architecture to the edge of the network, with the aim to mitigate the above-mentioned challenges. With fog, the latency-sensitive application can be processed at the edge of the network, near end devices, while delay-tolerant and computational intensive components can be processed in the cloud. Therefore, the greatest advantage of fog computing is low latency, provided by enabling data processing at specific locations at the network edge, i.e. at fog nodes. Densely-distributed points for gathering data generated by the end devices are also provided. Furthermore, cloud computing is not viable for most of the Internet of Things (IoT) applications and fog computing can be a promising alternative. However, it should be emphasized that fog computing is beyond IoT and comprises other aspects of communication, such as content provisioning.

Fog computing is considered as a promising solution to support the tasks with bandwidth, latency and reliability constraints. There is a full potential to fulfill a wide adoption of fog computing in various applications, ranging from smart cities, transportation, surveillance, healthcare and agriculture and military to large-scale industries. In this paper, the possibilities of fog computing application in logistics systems are presented.

The paper is organized as follows. After the introductory remarks, Section 2 provides an insight into the concept of fog computing, the architecture and differences compared to cloud computing. In Section 3, the possibilities of fog computing deployment in logistics systems are observed. Some open research issues in fog computing are presented in Section 4. Concluding remarks are given in Section 5.

2. KEY CHARACTERISTICS OF FOG COMPUTING

Fog computing is introduced in order to support geographically distributed, latency sensitive and Quality of Service (QoS)-aware applications. The concept is first initiated by Cisco (2014), with the aim of extending cloud computing to the edge of a network. The term *fog* refers to as *the cloud close to the ground*, i.e. *From cOre to edGe computing*. It is a highly virtualized platform providing computing, storage, and networking services between end users and cloud data centers.

The main fog capabilities include security, cognition, agility, latency and efficiency, according to OpenFog (2017). Fog computing is characterized by low latency and location awareness, heterogeneity, end device mobility, provides wireless access, capacity for processing numerous nodes, supports geographic distribution and real-time applications, according to Mukherjee et al. (2018). Numerous geo-distributed devices, such as end user devices, routers, switches and access points, are placed at the edge of the network. Their management is performed in a distributed manner. The aim of fog computing is to avoid upload/download data to/from the core network, using the edge devices which are in proximity. Edge devices in fog computing can release some of their resources to support the demands of their neighboring devices. Only the task that is not possible to be provided by the edge device is sent to the core cloud resources for further processing.

2.1 Definitions of fog computing

There are several definitions of fog computing. According to Vaquero and Rodero-Merino (2014), fog computing represents a concept for enabling communication and cooperation between heterogeneous (wireless and potentially autonomous) ubiquitous and decentralized devices, and between devices and the network, in order to satisfy processing and storage requests, without third party's involvement. OpenFog Consortium in OpenFog (2017) defines fog computing as "a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from cloud to Things". According to IBM (2016), fog computing and edge computing can be considered as the same computing paradigm, that enables placing some processes and resources at the edge of the cloud, instead of establishing channels for cloud storage and utilization. In Naha et al. (2018), fog computing is defined as a distributed computing platform where virtualized and non-virtualized end or edge devices perform most of the processing. Fog computing is also associated with the cloud for non-latency-aware processing and long-term storage of useful data. This definition considers all devices with computing and storage capacity as fog devices and identifies the role of the cloud in the fog computing environment.

2.2 Architecture of fog computing

The architecture of fog computing can be presented as the hierarchical structure, according to Sarkar et al. (2018). This structure can be illustrated as shown in Figure 1.

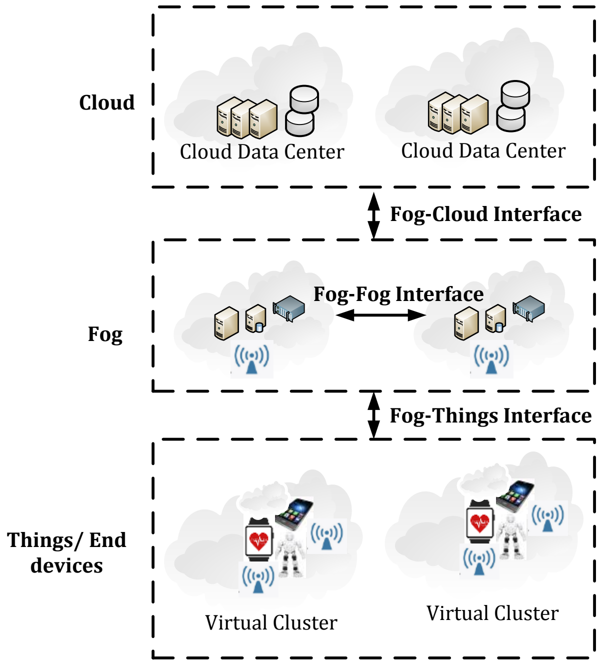

Figure 1. The three-tier fog computing architecture

The first tier comprises end devices, IoT enabled devices including sensor nodes, smart devices, etc. These end devices can also be referred to as Terminal Nodes (TN). The second tier represents the fog computing layer. The fog nodes in this layer are routers, gateways, switches, etc. These fog nodes can share storage and computing resources. The third tier is the cloud layer, and consists of cloud data centers, providing sufficient storage and computing resources.

The architecture of fog computing can also be presented as the layered structure, by Aazam and Huh (2016). The layered architecture consists of the following layers: physical and virtualization layer, monitoring layer, preprocessing layer, temporary storage layer, security layer and transport layer. Physical TNs and virtual sensor nodes are placed in the physical and virtualization layer. The energy consumption of underlying physical devices and provisioning of requested tasks is analyzed by the monitoring layer. Data filtering, data trimming and other data management related tasks are performed in the preprocessing layer. The temporary storage layer is in charge of storing the data only for a limited time. The security-related issues are managed in the security layer. Data transmission to the cloud is performed in the transport layer.

2.3 Difference between fog and cloud computing

Fog computing and cloud computing are interdependent in terms of providing storage and computational resources. However, they are different computing paradigms. The main differences are summarized in Table 1. Fog computing extends storage and computational resources, communication and networking provided by cloud computing near to end devices. Hence, fog is a promising solution for resource-constant devices. Due to high latency, real-time interactions are not possible for the cloud. In fog computing, end-to-end latency is significantly reduced. However, the reliability in service provisioning is higher in the case of cloud computing.

Table 1. Comparison of cloud computing and fog computing

Feature	Cloud computing	Fog computing
Management	Centralized	Distributed fog nodes can be controlled in both centralized and decentralized manner
Size	Very large cloud data centers	A large number of small fog nodes
Latency	High	Low
Resource optimization	Global	Local
Access	Fixed and Wireless	Mostly wireless
Mobility	Low	High
Computation capacity	Very high	Low
Scalability	Average	High
Application type	Non-latency-aware	Latency-aware
Nature of failure	Predictable	Highly-diverse
Deployment costs	High	Low

Furthermore, cloud computing aims at overall resources optimization, while fog computing includes local resources allocation and management. However, fog computing enhances overall system efficiency. The rate of failure in the fog is high, due to dominant wireless connectivity and decentralized management. It should be noted that fog cannot replace cloud computing. Both technologies contribute differently to performances improvement.

2.4 Comparison with similar paradigms and technologies

Fog computing deploys computing resources near underlying networks, located between cloud resources and edge devices, in order to provide more efficient service and application provisioning. There are several similar computing paradigms, such as Mobile Cloud Computing (MCC), Mobile-Edge Computing (MEC) and Edge Computing (EC). These technologies do not exclusively depend on cloud resources.

Remote provisioning of mobile services can be performed with the support of MCC near end devices, in accordance with Sanaei et al. (2014). MCC can overcome computational and storage limitations of resources of smart mobile devices. It is a mobile computing technology, providing unrestricted functionality, mobility and storage through heterogeneous network connectivity. It is expected that MCC will be implemented in education, urban and rural development, healthcare, applications such as augmented reality, etc. Mobile computing requires essential changes to cloud computing, including a low-latency middle tier, infrastructure optimization for mobile applications and introduction of mobile cloud services.

The co-location of computing and storage resources at the base stations of cellular networks is enabled in MEC, by Naha et al. (2018). In addition, MEC can be connected or disconnected to cloud infrastructure in a remote location. Therefore, the architecture of MEC can be two or three-tier. In such an environment, a MEC server should be deployed near base station towers, in order to provide data processing and storage at the edge of the network. The participants in this environment are the following: mobile end users, network operators, Internet infrastructure provider and application service provider. Mobile end users require service provisioning. Network operators are in charge of management and maintenance of the base station operation, mobile core network, and MEC servers. Internet infrastructure providers enable connectivity to the Internet, while application service providers host the application servers in the Content Delivery Network (CDN) or within data centers. End users' requests are being served by the closest MEC, instead of forwarding it to remote Internet services. If it is not possible to serve the request at the MEC server, remote CDN or data center will serve the given request.

Edge computing deploys edge devices or edge servers to provide computation facilities. Generally, edge computing is more focused on the IoT devices, and less on cloud-based services, by Shi et al. (2016). The aim of edge computing is to provide computation facilities at a closer location to the data sources. Edge nodes perform data storage and processing. The edge device can also to distribute requests for service provisioning and provide service on behalf of the cloud to the end users. In such a situation, edge devices need to satisfy numerous requirements, including privacy, reliability and security.

3. POSSIBILITIES OF FOG COMPUTING APPLICATION IN LOGISTICS SYSTEMS

With the advancements in the technology and the appearance of Industry 4.0, the whole logistics process, from storing to shipping products, can be performed using intelligent technologies, with no manpower needed. Advances in the Internet of Things, robots and drones also reduce the need for manpower in logistics systems. Therefore, the efficiency in logistics procedures is significantly improved. In this Section, the possibilities of fog computing application in an intelligent logistics center and supply chain management are described.

3.1 Fog computing application in an intelligent logistics center

An intelligent logistics center can be described by Lin and Yang (2018). Suppliers' trucks deliver cargos to the receiving area. Once cargos are uploaded, they are moved by mobile robots to the warehousing space through Radio Frequency Identification (RFID) door, in order to confirm the quantity of cargos from each supplier. Robots can classify cargos and shift them to a warehouse space, and concurrently update data of inventories of the space in the given system. In addition, robots can extract the required products from the warehouse space, and move them to the picking area depending on the received customer orders. The best routing path is selected by each robot. Thus, the collisions between robots are avoided. Once receiving a task of picking a product, a robot can perform the delivery of the required product to a workstation. Afterwards, the product is picked up and placed to the conveyor. Along a conveyer, the product is posted by a tag and then moved to the sorting area. Using RFID sensing doors, the amount of products is confirmed. After sorting, products are moved to the shipping area, where robots move them to the trucks which deliver products to customers.

In observed intelligent logistics center, cloud resources are located and managed in a centralized manner. If the factory area is too large, latency is significantly increased in communication between numerous IoT sensors and centralized cloud. Distributed fog computing can be a promising solution for high latency in the system with thousands of IoT devices in a centralized cloud computing system. A part of the computing tasks for operations in the logistics center can be finished using only local information from nearby fog computing resources, instead of from the centralized cloud. Thus, tasks can be finished flexibly and more efficiently. Furthermore, fog computing implementation and integration with the IoT environment can lead to reductions in power consumption for over 40%, according to Sakar and Misra (2016).

An intelligent computing system in a logistics center consists of a cloud center, gateways, fog devices, edge devices, sensing devices, automated guided vehicles (AGV), robots, machines, etc. Usually, locations of the cloud center and sensing devices are fixed. Some sensing devices are mobile, however, their movements are constrained. The deployment of gateways, fog and edge devices in the logistics center differs from other deployment applications. For example, the deployment of fog computing in vehicular networks or smart cities is of large scope and open space, while the deployment in logistics center is performed in a relatively small scope and in closed space. Compared to some production factories with the harsh environment (such as refineries and nuclear power plants), where all devices may be restricted to the harsh environment, in logistics center deployment only placements, package, and delivery of products are concerned.

The framework of a computing system that can be deployed in a logistics center is shown in Figure 2. It consists of a cloud computing center, gateways, fog devices, edge devices and sensing devices.

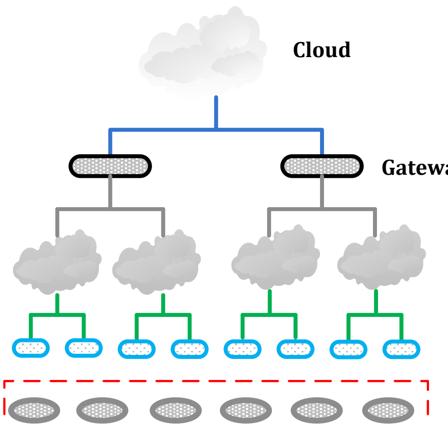

Figure 2. The architecture of fog computing in a logistics center

The cloud center provides the access to physical and virtual resources in different deployment models, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). The gateway connects incompatible network facilities. Fog device collects data from extreme edges and transmits data to the cloud center through gateways. Edge devices are deployed close to physical machines, conveyor and warehouses in the logistics center. Thus, decisions based on local information can be determined locally, without the involvement of cloud computing. It is important to emphasize that edge computing devices are deployed on terminal facilities or sensors, while fog computing devices are deployed on the data center nodes within a certain region. Additionally, the main function of edge devices is to respond to requests of terminal facilities, while fog devices extend cloud services to network edges. Sensing devices in the logistics center aim at monitoring boy shuttles, AGVs and robots. In the computing system deployed in a logistics center, edge devices are used for data transmission to fog devices and provide AGVs real-time information about trajectories of other AGVs. Afterwards, fog devices temporarily store and process the data, send determined decision back to AGVs and forwards the data to cloud center for historical analysis and long-run storage.

3.2 Fog computing deployment in a supply chain management

Supply chain comprises the sequence of organizations involved in the different processes and activities that produce value in the form of products and services. Supply chain management consists of several phases: planning, implementing and controlling the operations of the supply chain. Global supply chain scenarios are characterized by massive amounts of data collected for processing from numerous geographically dense endpoints. Storing and analyzing data in a centralized, remote data center is not optimal due to several reasons. Foremost, the data volume generated by devices may exceed the network bandwidth. This may result in delays. Data transmission to a remote cloud data center may introduce an unacceptable delay for latency-sensitive applications, especially in situations when a real-time response is required (for instance, automatically alerting the shipping manager if the critical value of the observed parameter is exceeded). In addition, retailers in a highly competitive market need to provide their customers with the possibility to buy anywhere, receive anywhere, and return anywhere. This requires the ability, in real-time, to locate and allocate available inventory from any location, such as a store, distribution center, in transit, or on order from the manufacturer. Network and compute resources need to be configured in a more suitable architecture, where computing facilities are split between local sites (for temporary data storage and processing) and the cloud (where the data is further analyzed and stored). Therefore, fog computing is a promising computing paradigm for supporting supply chain management, according to Musa and Vidyasankar (2017).

Tracking and monitoring the environmental conditions from the field to retailer can help the producer, distribution manager and retailer to calculate the remaining shelf time and to identify potential quality issues. A fog computing framework for supply chain management comprises three layers.

Layer 0 represents data producers, including RFID embedded sensors and other sensing devices. Data generated in this stage are related to different environmental parameters measured by the sensors, temperature, humidity, internal and/or external pressure, light exposure, etc.

Layer 1 represents monitoring and control layer. Control logic is executed through analysis of the sensor readings, which comprises computing alarms and generating events, which may trigger workflows through machine-to-machine or human intervention. Fog devices include active or smart readers and trucks as a mobile fog node. These readers are installed in the field, truck, dock doors and the retail display unit. Smart readers have the ability to store and forward data at specified intervals when the network connection is poor, to support business intelligence within the reader and the ability to be configured in order to provide alerts and notifications if a device fails. All sensor readings aggregated by the fog node are filtered and stored in a temporary buffer. A smart reader can serve as a processing hub, and the first processing stage of the system is performed by this layer. Truck as a mobile fog node consists of RFID tags, smart readers, Onboard Decision Support Unit (ODSU) and Event Notification Unit (ENU). The ODSU receives filtered sensor measurements from the smart reader and matches them against the critical values of the observed parameters. When the critical values are exceeded, the ODSU triggers an alarm and corrective actions or automatic adjustments are performed. The ENU manager is triggered by the ODSU after corrective actions are being performed. The ENU unit sends alerts to the distribution/warehouse manager and the driver.

Layer 2 represents cloud data centers. The main task of this layer is to store and analyze the entire history of the supply chain operations. This layer is in charge of determining the amount of product to be delivered to downstream retail stores/distribution centers and for providing optimal routes at each level of the supply chain.

4. OPEN ISSUES IN FOG COMPUTING

Fog computing is an evolving technology with the possibility to achieve wide adoption in many applications, including logistics systems. Despite its numerous advantages, there are some open challenges.

Since the number of connected devices is excessively increased, the number of levels in the fog layer may cause latency problems. Therefore, the number of tiers in a fog computing architecture must be determined. Deployment decisions are based depending on requirements related to the amount of task provided by each tier, the total number of sensing devices, the capability of each fog node and reliability of fog devices. Application and resource allocation is also an important segment of fog computing deployment.

Due to the diversity of devices and their available resources, fog computing is characterized by the dynamic and heterogeneous environment. Resource allocation and scheduling in the fog computing is more challenging in comparison with resource allocation and scheduling in cloud computing since fog uses idle resources available on any fog device. Therefore, the improvement of available resources prediction on each fog device is another important issue to be solved.

Fog devices' failure may occur due to hardware failure, software failure, end user' activity, or due to problems with connectivity, mobility or power source. Since the management of the devices is decentralized, and devices are mostly mobile, the probability of the failure is high. In order to satisfy the requirements of time-sensitive applications, it is necessary to ensure the uninterrupted connection between devices. The connection type and protocols used by different devices need to be coordinated, which is also an important research issue. A standard form of communication protocol is necessary so that generic applications can communicate and operate with different types of fog devices.

5. CONCLUSION

Fog computing is an emerging computing paradigm that attracts a lot of research attention since it supports latency-sensitive applications with low traffic congestion, low energy consumption and minimum bandwidth. It extends the computation, communication and storage facilities from cloud data centers to the edge of the network. Additionally, fog supports virtualization and represents a complementary technology to cloud computing. In this paper, the key characteristics of fog computing are indicated. The comparison with cloud computing, as the complementary technology, is provided. In addition, some similar computing paradigms are described and the comparison with fog computing is analyzed. The paper also analyzes the possibility of fog computing deployment in logistics systems, with the special emphasize on fog computing deployment in an intelligent logistics center and a fog computing framework for the supply chain management. In logistics systems, the deployment of fog computing can improve energy efficiency, reduce latency, reduce costs and supports mobility. Furthermore, the advanced automation of the manufacturing systems is enabled. Fog computing in logistics systems also contributes to the improvement of product quality, production efficiency, condition monitoring and decision making. Although fog computing has great potential to achieve wide adoption, it is still an emerging computing paradigm. Some research challenges and open issues are presented in the paper.

ACKNOWLEDGMENT

This work was supported by the Ministry of Education, Science and Technological Development of Serbia [grant number TR 32025].

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THE CONCEPT OF LOGISTICS 4.0

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Abstract: *The concept of Logistics 4.0 was created as a consequence of Industry 4.0, emergence of new technological solutions and the use of Internet in business systems. The aim of this paper is to present modern logistics trends, digitization of logistics and description of the concept of Logistics 4.0. The basic components of that concept are: automatic identification, real-time localization, automatic data collection, connectivity and integration, data processing and analysis and business services. The paper presents and describes some of the most important Logistics 4.0 technologies: Internet of Things, wireless sensor network, Cloud Computing, Blockchain, Big Data, robotics and automation, augmented reality, drones, 3D printing and automatic guided vehicles.*

Keywords*: Logistics 4.0, Industry 4.0, Internet, Digitization, Business.*

1. INTRODUCTION

Logistics is a field that has modified through history so that it always followed social, industrial and technological changes. Logistics 4.0 has been created in recent years as a consequence of the fourth industrial revolution and technological achievements of the 21st century. The development of ICT (Information and Communication Technologies) enabled new methods of data exchange, horizontal and vertical integration of value chains and new business models.

The aim of this paper is to describe the concept of Logistics 4.0, define its significance, components and technologies. The paper consists of six parts. The second part describes the influence of industrial revolutions on the development of logistics. Industry 4.0 is described in the third part. The fourth part covers the concept of Logistics 4.0, its basic components and technologies. The fifth part presents the advantages and challenges of Logistics 4.0. Conclusive considerations are given in the sixth part.

2. THE INFLUENCE OF INDUSTRIAL REVOLUTIONS ON LOGISTICS

Modern industry has been developing for several centuries and so far there have been four industrial revolutions, marked by innovations, changes, new production methods and influences on all other fields. Parallel to the industrial revolutions, the technological,

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social, demographic and market conditions changed in which logistics went through phases, from Logistics 1.0 to the present day Logistics 4.0. Figure 1 shows the evolution of logistics in the period from the first industrial revolution to date.

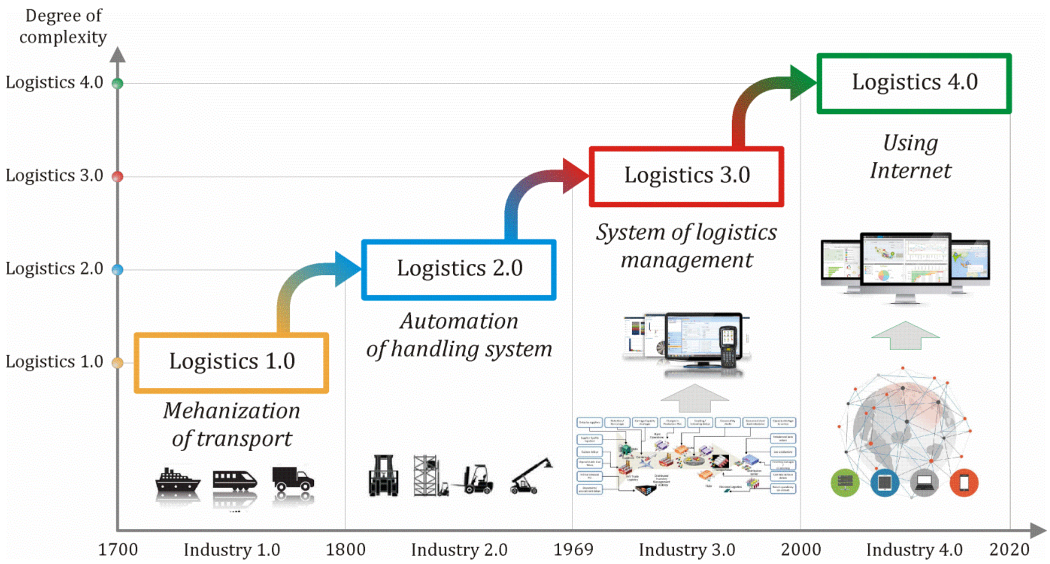

Figure 1. Evolution of logistics (adapted from Wang, 2016)

The first industrial revolution occurred in the 18th century and was marked by the invention of the steam engine and the transition from manual to machine production. This was the beginning of the massive use of transport of goods and passengers. For logistics, this period meant transport mechanization. Supply chain management was at the local level and logistics was based on push delivery flows. Warehouses were simple buildings in which raw materials and finished products were kept on the floor and movement of goods was carried out by hand carts. The owners of factories and shops dealt with the organization of production and logistic activities.

The second industrial revolution covers the period of the 19th and first half of the 20th centuries and was marked by the invention of production lines and mass production. This period is also called the technological revolution because there were many discoveries and inventions that changed civilization. Logistics started becoming more significant, new forms of transport developed, specialized transport means and systems for automatic handling of goods appeared. Supply chain management became global, logistic networks developed, new fields and companies that specialize in certain logistic activities and processes arose.

The third industrial revolution covers the period of three decades at the end of the 20th century and is marked by the development of ICT and their application in the field of production. The application of computers in production processes is the most important for this period. The Logistics & Supply Chain Management concept was introduced. Companies manage their supply chains on the global level, cooperate with suppliers, buyers, users and business partners, apply new business models and compare themselves with competition (Christopher, 2011). Logistics uses ICT, identification technologies and facilities monitoring, forms of electronic exchange of data, new technical solutions and software applications designed for managing processes and activities (Radivojević, 2016).

The fourth industrial revolution began in the 21st century and represented the integration of ICT with production processes and activities. Smart factories have automated processes and activities, digital business operations and information support on all organizational levels. The digital environment includes business partners, suppliers, buyers, users and the market with which the smart factory communicates through the Internet (Fonseca, 2018). In the new conditions, logistics has to provide visibility of real-time information flows, monitoring of market demands and direct users, personalization of products and services, decentralized autonomous management and global supply chains.

3. INDUSTRY 4.0

The term Industry 4.0 was first introduced in 2011 in Germany. Other European countries began making major changes in the same period, which were named Smart Factories, Industrial Internet of Things (IIoT) or Smart Industry (Hofmann and Rüsch, 2017).

The concept of Industries 4.0 implies connecting machines, products, systems and people that can share information and manage themselves and each other. In such a model, all objects are smart entities that have the ability to autonomously manage, control and communicate with the environment. Industry 4.0 understands complete automation and digitalization of business systems and their connections with the environment. This leads to the existence of a virtual reality model in which it is possible to monitor and manage all processes and activities. ICT, software applications and information platforms have the biggest role in the concept of Industry 4.0 because they provide connecting the virtual and physical business system.

Industry 4.0 is characterized by increased digitalization and mutual connection of products, value chains and new business models. This concept represents a new level of organization and value chain control throughout the whole life cycle of a product. The cycle begins with the idea of the product, customer request, design, production, placement of orders, delivery and ends with recycling. The value chain includes all activities of the supply chain and additional activities that are involved in creating the product value. Industry 4.0 is based on the availability of all relevant information in real time by connecting all links included in the value chain (Geissbauer et al, 2014).

The main components that form the concept of Industry 4.0 are (Santos et al., 2017; Vaidya, 2018): Cyber Physical System (CPS), Internet of Things (IoT), Internet of Services (IoS), Big data, Robotics, Cloud Computing (CC), Augmented Reality (AR) and Horizontal and Vertical Integration of the system. Various objects from the physical world are equipped with IoT devices which make them smart. In smart factories, there are smart machines, tools and equipment, and industrial robots that produce smart products. Data collection of all these objects enables the formation of a CPS in which data and process models correspond to the relations from the physical world. A virtual world is a digital version of reality in which processing and analysis of large amounts of data are performed by applying CC. The results of the analysis enable the possibility of monitoring and managing the physical world. An illustration of Industry 4.0 is given in Figure 2.

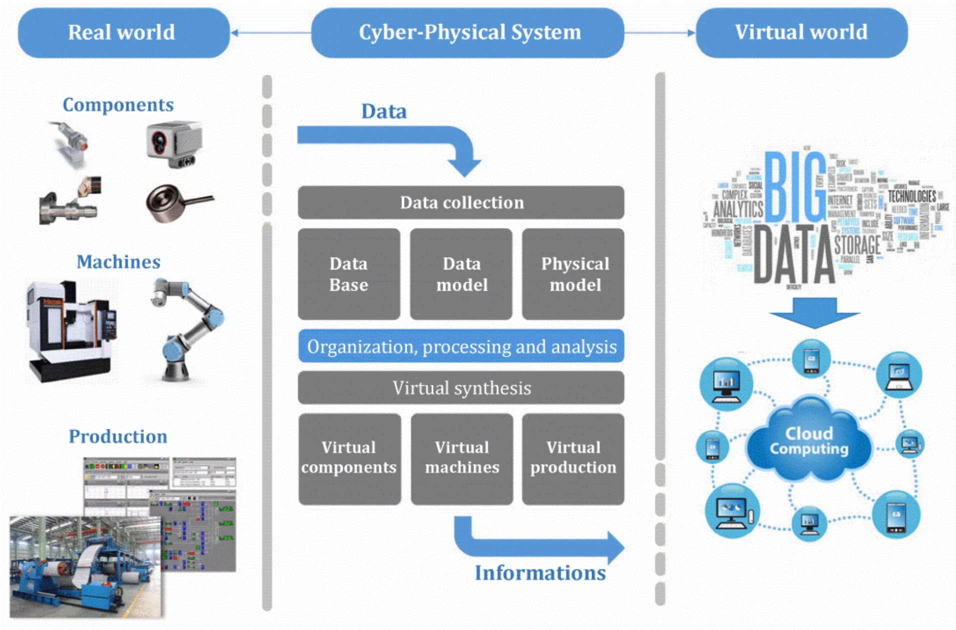

Figure 2. Illustration of Industry 4.0 (adapted from industry4.hu)

A research on the development, application and challenges of Industry 4.0 was carried out in 2015 and involved 235 German companies in the field of manufacturing, engineering, the automobile industry, electronics, information and communication (Geissbauer et al., 2014). The results of the research showed that companies will invest an average of 3.3% of their revenues in Industry 4.0 by 2020. These investments refer to the key areas in the value chain: supply chains, product development, planning, production, services and distribution. It is expected that 80% of value chains will be digitalized by 2020, productivity increased by 18% and about 110 billion Euros of revenue generated per annum (Geissbauer et al., 2014).

4. LOGISTICS 4.0

The term Logistics 4.0 first appeared in 2011 as a response and support to Industry 4.0. Today, the terms Supply Chain 4.0, Procurement 4.0, Marketing 4.0, Distribution 4.0, Warehousing 4.0, Inventory Management 4.0, Order Management 4.0, etc., can be seen. This represents the response of the logistic field to the development and requirements of Industry 4.0.

Logistics 4.0 should provide support the processes of Industry 4.0, from processing the market requirements and production planning to delivery of smart products to end users. The solution is in the digitalization of logistic activities and processes – the application of digital logistics. The characteristics of digitalization of logistic systems are (Kayikci, 2018):

- Cooperation – Digitalization enables the creation of virtual logistic associations (clusters) through which companies exchange data and information.
- Connectivity – Digitalization enables horizontal and vertical integration in supply chains and visibility of information in all chain links.
- Adaptiveness – The system of connected digital resources is flexible, as it can respond to different changes on the market (requests, users, suppliers, etc).

- Integration – In the digital world, integration of logistic systems is the process of connecting different computer systems and software applications, physically or functionally, in order to provide coordination of logistic flows.
- Autonomous – Smart objects, which have the possibility of communicating and independent decision making based on data processing of their own and environmental characteristics, are increasingly present in logistic systems.
- Cognition – Application of devices and systems for automation of tasks requiring human skills, knowledge, perception and cognitive skills (planning, reasoning and learning).

Logistics 4.0 is based on the latest ICT, software systems and the Internet which together should provide the following (Oleśków-Szłapka et al., 2019):

- Logistic management,
- Realization of commodity flows, and
- Realization of information flows.

Logistic management includes the planning, implementation and control of all logistic processes. The realization of commodity flows is a set of all activities that enable the movement of commodity flows from the source of raw materials to delivery of product to end user. Information flows are necessary to support realization of commodity flows and logistics management.

Logistics 4.0 is defined as smart logistics, because its components enable intelligent management of processes. The components of Logistics 4.0 are (Wang, 2016): Automatic identification, Real-time location, Automatic data collection, Connectivity and integration, Data processing and analysis, and Business services.

Automatic identification of all objects and participants in logistic processes, the possibility of locating them and data collection in real-time, enable quality management, planning and optimization. Data processing and analysis create new knowledge, conditions for intelligent management and new business services. There are numerous technologies that implement the stated components, and the most important are shown in Figure 3.

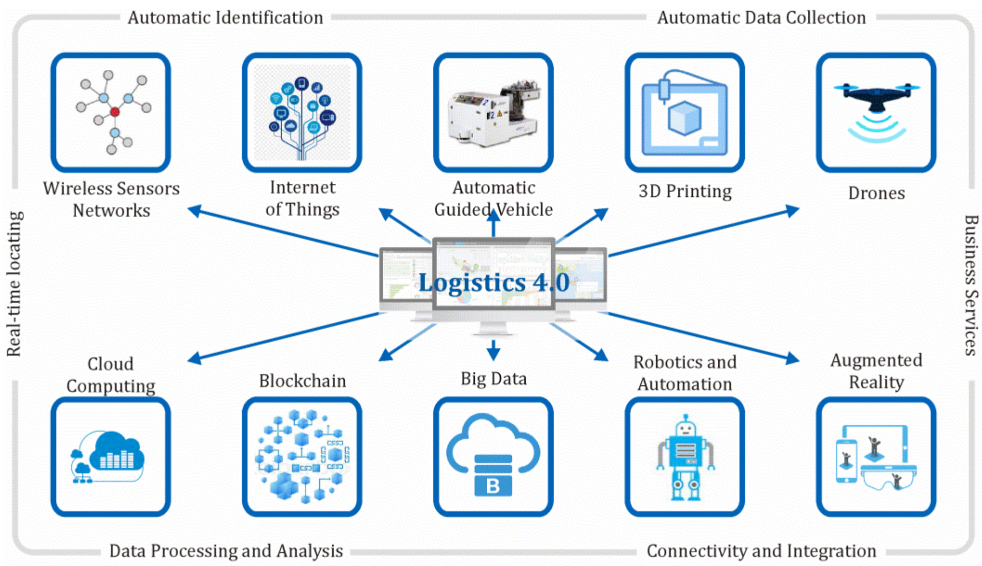

Figure 3. Components and technologies of Logistics 4.0

4.1 Internet of Things

IoT is based on the most contemporary ICT that enable marking, identification, communication and intelligent managing of things. In this concept, things become smart objects that have the ability of identification, communication and interaction. Realization of IoT enables the creation of a virtual model of virtual reality in which business models will be able to manage processes and activities in real-time on the basis of information on current state of objects. Identification technologies applied to different objects in logistics have led to the existence of smart containers, pallets, packing, packaging, vehicles, shelves, forklifts, infrastructure, ports, terminals, etc. Various models of connectivity through the Internet are present in logistic systems, which represent initial IoT solutions that lead to global connectivity of all participants and objects (Radivojević et al., 2017).

4.2 Cloud Computing

CC means the use of various computer services through the Internet. The main characteristics of CC are: providing services at the request of the user, broad network access, mutual using of resources, flexibility in use and measured use. This means the users can use computer resources when and however much they need; they can access the Internet through different devices; a large number of users can use the same resources; cloud systems automatically monitor and measure the use of resources for each user (Mladenović, 2018). CC provides numerous advantages to logistic companies as it enables quick, efficient and flexible access to IT (Information Technology) services and innovative solutions in supply chains. Logistic companies no longer need to invest in the procurement of software applications and hardware infrastructure, develop their own IT sectors and coordinate integration with business partners.

4.3 Big Data

Big Data include technologies for storing, transmitting, processing and analysis of large amounts of data that cannot be stored, processed and analyzed by traditional tools and data base technologies. The application of different analytical methods enables the formation of new information and knowledge from such data sets, which can influence management and decision-making in the business system (Jeske et al., 2013). Logistics 4.0 implies a significant increase in the amount, diversity and speed of data processing. By applying Big Data analytical methods and Data Mining (DM), companies can create additional values and apply new business models. DM enables finding hidden information, relations, relationships, rules and logic that exists among the data. By using DM, it is possible to predict market trends, user behavior, find causes of disorders, etc (Radivojević, 2016).

4.4 Blockchain

Blockchain technology can be described as a decentralized and distributed system of all transactions in a certain segment of work. One block represents a set of data and information on one transaction and it is added to the previous block, forming a chain. The blockchains can be found with all participants in business transactions, enabling visibility and availability of information. The possibilities of blockchain technologies in logistics are faster and more reliable logistics in global trade; improved monitoring and visibility of goods in supply chains; automation of commercial contracts between business partners through smart contracts based on blockchains; etc. Blockchain in logistics and supply chains provides security, protection and tracking of information, transparency of data for all partners and users, financial savings through smart contracts, development of new business models, etc (Kückelhaus and Chung, 2018).

4.5 Wireless Sensor Network

Wireless Sensor Networks (WSN) are systems consisting of a sensor and wireless communication network. WSN enable collection and transfer of data between sensor nodes, access devices and network users. Sensors are used to identify objects and their physical characteristics – characteristics of goods, transport and transshipment means, containers, locations in warehouses and sales facilities, equipment and traffic infrastructure, etc (Radivojević, 2016). Some examples of the use of WSN in logistics are (Kückelhaus and Chung, 2018): measuring vehicle load is based on WSN and 3D cameras; quality control of goods based on analysis of data obtained from sensors; sensors are installed in transport and transshipment equipment, infrastructure and facilities in logistics; work clothes with built in sensors improve safety and health conditions of workers; etc.

4.6 Robotics and Automation

Applying robotics and automation in production processes enables: improved quality of finished products and safety levels, reduction of errors, necessary labor and costs, improving quality standards, etc. Development of robotics suggests that robots, in the future, will be faster, more precise, flexible and affordable, which will accelerate their use. The contemporary market sets faster demand, efficiency and faster responses to users' requests to logistic companies. There are numerous examples and possibilities for applying robots in logistics (Kückelhaus and Chung, 2018): a fleet of intelligent robots for collecting, commissioning and sorting of goods; robots for unloading containers based on OCR (Optical character recognition) technology and intelligent control; robots used for sorting goods in delivery vehicles or self-delivery of goods to the point of collection, etc.

4.7 Augmented Reality

Augmented Reality (AR) enables elimination of borders between the physical and digital world, providing users with a view of reality expanded by information from the digital world. Digital layers of information are shown on the device, creating a picture of enlarged reality to the user. The devices may be glasses, tablets, laptops, mobile phones and similar. AR provides the right information at the right time and in the right place. Some possibilities of AR application in logistics are: application of smart goggles in warehouses for collecting, sorting and packing operations; smart handling of forklifts and vehicles; smart delivery of goods to the end user using smart goggles, etc. Research and development of AR devices, the possibility of recognizing images and connecting devices with software applications will create conditions for application of AR in all logistic processes (Kückelhaus and Chung, 2018).

4.8 Drones

Unmanned Aerial Vehicles (UAVs) – drones will not replace the traditional method of transport but they can be used for safe operation in remote and potentially dangerous locations. Commercial use of drones has been in the phase of testing in recent years in some large companies (Amazon, Google, DHL). The greatest application of drones is expected in intralogistic processes, monitoring of logistic activities and delivery of goods to end users. Intralogistic operations can be simplified by using drones for transport between production units, urgent delivery of spare parts or for transfer of goods from warehouses to retail sections within the same facility. Drones can be used for checking the state of facilities and equipment, stock control and checking incoming vehicles on receiving gate. Drones for delivery of goods to end users may transform the existing methods of delivery in large cities and rural areas (Kückelhaus and Chung, 2018).

4.9 3D Printing

3D Printing is a contemporary technology for creating three dimensional objects which has started to be applied in various fields, from the pharmaceutical industry and production of medical devices to production of spare parts and aircraft parts. 3D printing will considerably impact logistic processes and services: regional logistic networks will become more complex, new supply chain strategies will be developed; companies will be able to offer new logistic services in the field of spare parts supply; logistic providers can define a global 3D platform with a digital model base; personalization of products and services, in conformity with users' requirements, is realized by 3D printing in the nearest distribution center. 3D printing allows delivery of goods at the request of the user, an increase in delivery and decrease in stock costs (Kückelhaus and Chung, 2018).

4.10 Automatic Guided Vehicle

Automatic Guided Vehicles (AGV) have been in use for more than 60 years in various fields of industry, production processes and warehouse facilities. AGVs are unmanned vehicles based on sensor and video detection technologies, artificial intelligence and other ICT. AGV vehicles that are used in logistic processes may be: tractors for towing trailers, vehicles for unit loads, pallet trolleys, trolleys with additional forks, light load vehicles, assembly line vehicles, special vehicles, etc. These vehicles are used for traditionally demanding tasks; they enable automatic handling of freight and equipment. The application of AGVs in logistic processes decrease expenses and labor, increase reliability, productivity, safety and quality of work, reduce the risks of human errors and damaged, etc (Kückelhaus and Chung, 2018).

5. ADVANTAGES AND CHALLENGES OF LOGISTICS 4.0

The introduction of Logistics 4.0 is becoming an imperative for all companies that want to stay on the market. This requires large investments, changes in the methods of work and decision-making, contemporary education and employee training. There are no concrete data on the effects of applying the concept of Logistics 4.0, but various papers state numerous possibilities and improvements which may be realized by logistic companies and users. Some advantages of Logistics 4.0 are (Oleśków-Szłapka et al., 2019):

- Complete integration of the physical and virtual world;
- The possibility for users, machines and systems to have communication in real-time and possibilities of independent decision-making of all participants in logistic processes;
- Improvement of all processes in supply chains, reduced risk of structural or organizational errors during realization of a process and possibility of decreasing the process realization time in accordance with users' requests;
- Accessibility of contemporary technologies for processing and analyzing large quantities of data;
- Improvement of business performance and access to all resources;
- Increased visibility and flexibility of supply chains, etc.

The disadvantages of Logistics 4.0 are primarily the consequence of high demands relating to organizational, technical and software solutions. A company has to change the way it operates, its organization of management and apply the latest IT solutions so that it could meet the preconditions for introducing a new concept of smart logistics. The challenges facing Logistics 4.0 are: high introduction and implementation costs, strict requirements in view of hardware infrastructure, requirements for application of process-oriented management methods, etc. The solution to the stated challenges are good implementation, the commitment of the whole company to changes, motivation of employees for further training and development of their own intellectual resources that support changes (Oleśków-Szłapka et al., 2019).

There is no data on logistic companies which completely encompassed the process of implementing Logistics 4.0 in available literature, but there are many examples of the application of some components of Logistics 4.0 (Figure 4). Most often this refers to large and successful companies that have their own IT sectors or cooperate with IT companies through innovation centers, open laboratories or projects (Kückelhaus and Chung, 2018).

Amazon's warehouse robots | AR in DHL warehouse | AGV in port Hamburg

Figure 4. Examples of applying some components of Logistics 4.0

6. CONCLUSION

Throughout history, the field of logistics has developed and continuously adapted to the needs of the population, current technological trends and industry. This paper described the concept of Logistics 4.0 which represents the response to the requirements of Industry 4.0. Logistics 4.0 includes the latest ICT, software applications, new business models and concepts that together enable complete digitalization and automation of logistic processes and activities.

This concept imposes numerous challenges to companies: large financial investments, implementation risks, strict infrastructure requirements, new levels of education and skills of the employees, etc. At the same time, this concept has not been fully defined because new technologies are continuously being developed and new solutions applied. Applying the Logistics 4.0 concept for companies is not a matter of choice (*should it be applied?*) but a matter of time (*when do we start?*).

ACKNOWLEDGMENT

This work was supported by the Ministry of Education and Science of the Government of the Republic of Serbia through the projects TR 36005 for the period 2011-2019.

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LOGISTICS INDUSTRY 4.0: CHALLENGES AND OPPORTUNITIES

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Abstract: *The frequently emerged question between logistics practitioners and theoreticians is how much technology can be leveraged to address the challenges and opportunities that arise in the logistics industry? The recently coined term - Industry 4.0 is the paradigm that explains the possibility of information and communication technologies to digitally transform processes in all industry sectors, including logistics. In this paper we are introducing a new term – Logistics Industry 4.0. Logistics Industry 4.0 refers to several emerging technologies, such as internet of things, big data, cloud computing, artificial intelligence, robotics and blockchain and their implementation in three key aspects of typical supply chain: supply of raw materials, production, and wholesale/retail and two logistics activities: transportation and warehousing. We will present the most promising technologies that will transform logistics processes in the near future and the associated challenges and opportunities.*

Keywords: *Industry 4.0, transformation of logistics processes, digitalization, Logistics Industry 4.0.*

1. INTRODUCTION

The first industry revolution introduced mechanized manufacturing with equipment powered by water and stem. The second industry revolution introduced mass production using electric energy. The third industry revolution introduced the use of electronics and computers in general to automate manufacturing. All revolutionized processed in three previously mentioned industry revolutions are related with the movement of goods (transport) and manufacturing activities which are key logistics sectors. Therefore, logistics experts can ask a question: what is the form of today's industry revolution and how it impacts logistics processes? The next industrial revolution is focused on creating interconnections between physical and virtual systems (Ilin and Groznik, 2013). This practically means the formation of global networks which shall include product and storage facilities in the form of cyber-physical systems which shall communicate independently, generate and control themselves (Maslarić et al., 2016). Thus material, information and financial flows will be transformed.

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Recently, the term – Industry 4.0 is adopted as an indication of industry change. Industry 4.0 is coined in 2011 by German engineers as an idea of a fully integrated industry (Bauernhansl, 2014). In several recent research papers the term – Industry 4.0 is primarily related to cloud computing, Internet of Things (IoT) and big data and their applications in different industries (Hofmann and Rüsch, 2017; Witkowski, 2017). However, other emerging technologies, such as robotics, Artificial Intelligence (AI) and blockchain also deserve attention because of their high potential in the process of digitalization and transformation of logistics activities. Therefore, we are introducing a new term – Logistics Industry 4.0 which encompasses previously mentioned Information and Communication Technologies (ICT) and their opportunities and challenges to digitally transform logistics processes.

The rest of the paper is organized as follows. In the second section the new term – Logistics Industry 4.0 is demystified. The related challenges and opportunities are also highlighted. In the third section implications for supply chain management are emphasized. The fourth section explains key challenges for logistics companies. The paper concludes with a key findings and implications for the future work.

2. LOGISTICS INDUSTRY 4.0: DEMYSTIFICATION

"Logistics is being transformed through the power of data-driven insights."

(Chung et al., 2018)

In logistics, data availability exponentially increases with the increased use of sensors and a key question is how to efficiently and effectively ensure data quality? Logistics companies are trying to adopt innovative IT solutions to improve intra-operational processes and achieve end-to-end visibility within supply chain.

In this section we will present the most promising digital topics that are expected to transform logistics industry in the near future. The focus is on IoT, cloud logistics, big data, AI, robotics and blockchain technology and their impact on key logistics activities (Figure 1).

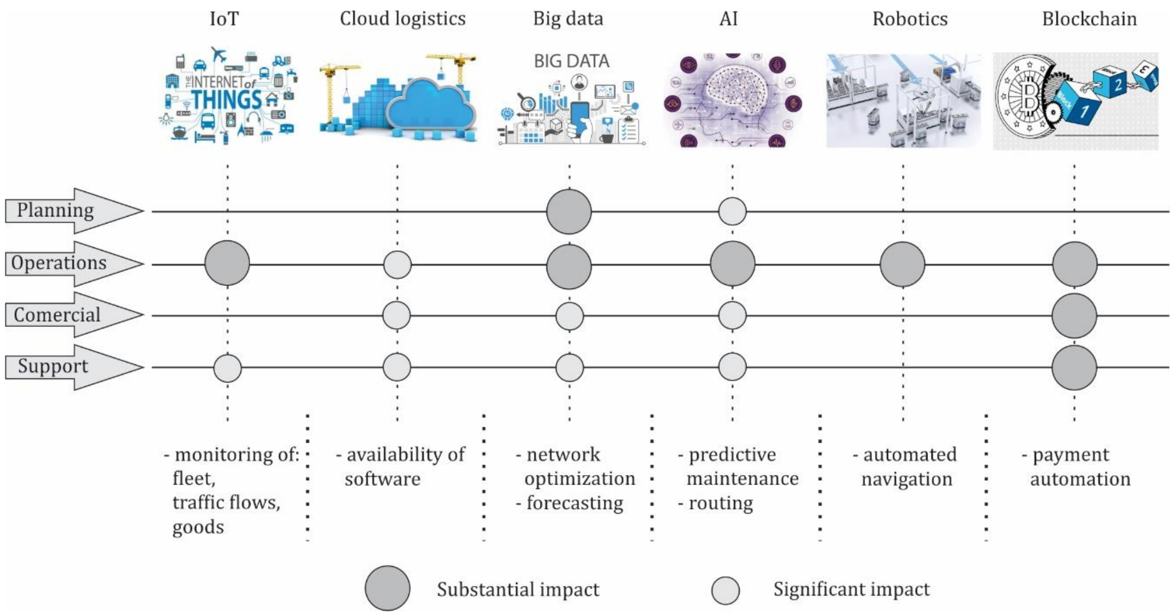

Figure 1. Impact of Industry 4.0 on logistics (adapted from Glass, 2018)

2.1 Internet of things

IoT technologies virtually connect physical objects by sensors and allow them to receive, store and send information which may improve decision-making process. In logistics, IoT can be used to enhance vehicles, infrastructure and services and deriving improvements for transport system operators and users (Lyons, 2017). According to Allied Market Research the global connected logistics market is estimated to substantially grow to $27 billion until 2023 (Allied Market Research, 2018). The key opportunity from using IoT is real-time connectivity which offers potential to improve quality of services and increase control. However, the total costs of implementation are still high and issues like security concerns and lack of legal regulation presents major concerns for decision makers in logistics companies to opt for the implementation of IoT. The development of low-cost IoT networks and decrease in sensor prices may shift the current trend.

2.2 Cloud logistics

Cloud logistics refers to new business model called Logistics-as-a-Service (LaaS). By using LaaS logistics practitioners have the opportunity to use innovative IT solution customized for logistics industry. LaaS is changing the form and function of information technology infrastructures making supply chain information collaboration easy and feasible (Ilin and Simić, 2013). LaaS also offers easier way to establish efficient and effective logistics processes which significantly decrease costs and increase time savings. A pay-per-use politics and scalability are particularly suitable for small and medium-sized logistics companies to be competitive on the market. Today, more than 50% of logistics providers use cloud-based services and a further 20% are planning to do so in the near future (Brandl, 2016). However, the three potential obstacles may inhibit LaaS adoption: security concerns, compatibility with other IT solutions within logistics company and performance issues.

2.3 Big data

Big data is the “data” characterized by the four “V”s. They are volume, variety, velocity and value. Big data has already changed logistics industry by transforming large-scale structured and unstructured data into valuable information for logistics managers during decision-making processes (Simić and Ilin, 2017). There is a huge potential in turning unused data into competitive advantage on the market. Forecasting of market demand and new business models customized for customers are some of the examples of advantages achieved by implementing big data in logistics. The advancement of big data analytics along with AI will allow real-time route optimization, holistic forecasting of fleet capacity and demand for goods and reduction of risk through the supply chain network. The biggest threats to the wider adoption of this paradigm in logistics are security issues.

2.4 Artificial intelligence

AI technology is an integral part of almost every IT system today. It is closely related with IoT technology which allows data collection by sensors, cloud computing technology and big data paradigm. AI can be observed as a set of technologies interrelated with the aim to solve complex problems. Typically, AI technology consists of three types of components: sensing, processing and learning. Sensing components refer to data obtained (usually by sensors) from the physical world. Processing components refer to set of algorithms implemented in various software solutions with the aim to process data. Learning components refer to capturing patterns of structured and unstructured data. In logistics, AI can provide optimal solutions for vehicle routing and consequently cost reduction, ensure predictive forecasting for demand, accelerate decision-making and increase customer satisfaction through the personalization of logistics services. The strongest challenge is high implementation costs for a logistics company.

2.5 Robotics and automation

Robotics is a science field closely related with AI and further with IoT, cloud computing and big data. Robotics has a great potential to be implemented in dynamic environments, such as production and warehousing. According to a DHL research, 80% of warehouses are manually operated today (Bonkenburg, 2016), which leaves plenty of opportunities for automation. In highly automated warehouses autonomous vehicles are used for the realization of transport processes. Autonomous vehicles provide higher speed, precision, safety and tracking capability than to forklifts, hand pallet trucks and high rack pallets (Gu et al., 2007). Also, autonomous vehicles can be reprogrammed, permanently operational without human intervention, modular and easily integrated with other robots and devices. Compared to traditional warehouses, highly automated warehouses provide a high degree of flexibility and lack of the need for installation of fixed infrastructure (Vis, 2006). However, significant resources need to be invested in the implementation. Still, technological advances may decrease required resources in the near future.

2.6 Blockchain

A blockchain is a decentralized, distributed and public digital ledger that is used to record transactions across many computers so that any involved record cannot be altered retroactively, without the alteration of all subsequent blocks (Economist, 2015). Blockchain technology basically allows shift from a centralized to a decentralized and distributed database system. The greatest potential of its application in logistics lies in global trade, where solutions that reduce supply chain trade barriers can increase global GDP by nearly 5% and global trade by 15% (Moavenzadeh, 2013). The potential advantages also include increased transparency, traceability and speed of goods deliveries, decreased overall costs and digitalization of all key documents (such as invoice) with stakeholders participating. However, since logistics industry is highly fragmented the adoption of blockchain technology in various industries will be very costly and unpredictable. Also, legislation regarding this subject need to be defined more thoroughly in the near future.

3. LOGISTICS INDUSTRY 4.0: IMPLICATIONS FOR SUPPLY CHAIN MANAGEMENT

The following conceptualization shows in which direction the transformation of supply chain management will occur (Figure 2). There are digital and physical world and interconnections between them. In virtual world this concept implies an integration of data networks and ICTs and in the physical world this means establishing personalized transport services and optimized distribution of goods. Autonomous vehicles and robots are some of the examples of innovative ICT solutions that enable self-control of logistics subsystems and their mutual interconnections. Sensor data are collected in the physical world along the entire closed-loop supply chain. Traditional technologies, such as radio-frequency identification or global positioning system, also produce a vast amount of data. Furthermore, there are other data sources relevant to Supply Chain Management (SCM) (e.g. digital clickstreams, camera and surveillance footage, imagery, wikis and forum discussions) that usually produce unstructured data. In total, there are tremendous amount of data that need to be processed instantly. Through the connectivity layer data analytics improve decision-making and add value to logistics services (Figure 2).

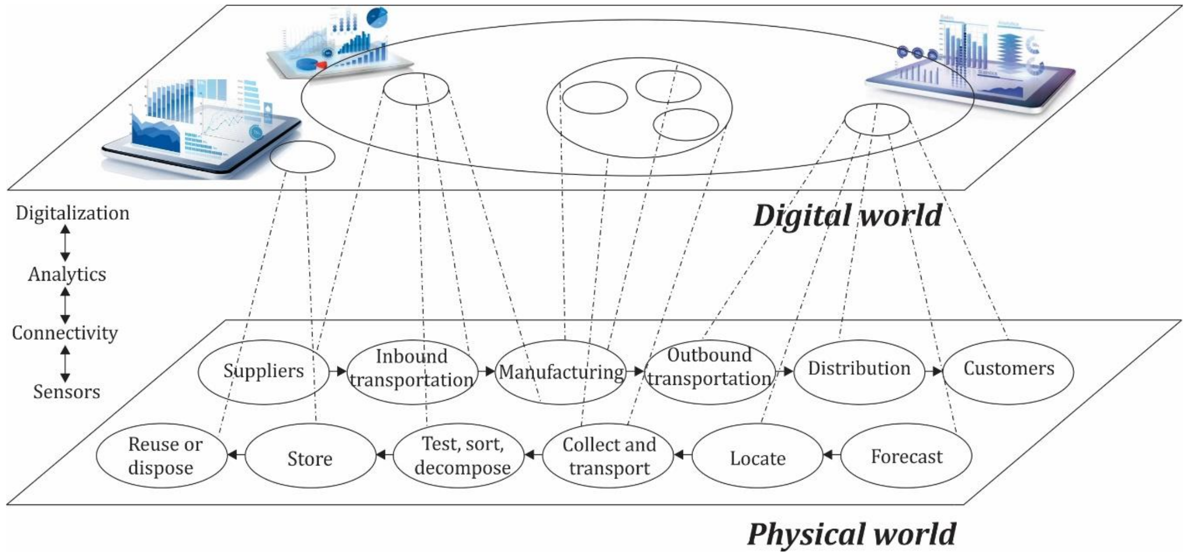

Figure 2. Transformation of supply chain management

3.1 Implications from theory

In previous research papers the concept Industry 4.0 in logistics have been investigated in specific intra-logistics areas, such as production logistics (Qu and Liu, 2015) and cross-organizational concepts, such as just-in-time, just-in-sequence and Kanban (Hofmann and Rüsch, 2017). Our selection is based on three key aspects of typical supply chain: supply of raw materials, production, and wholesale/retail and two logistics activities that connects previously identified aspects: transportation and warehousing. The authors used the publication databases SCOPUS, Web of Science and Google Scholar to highlight the importance of previously mentioned concepts. The databases were searched with respect to publications with a clear reference to the concepts in either their title, abstract or keywords. The obtained search results are presented in Table 1.

Table 1. Search string results

Supply chain management	*SCOPUS (title, abstract or keywords)*	*Web of Science (title only)*	*Google Scholar (title only)*
supplier	103	0	3
production	1625	73	208
wholesale/retail	1/15	0/0	0/0
transport	72	2	7
warehouse	42	5	8

It can be noticed (Table 1) that the term – Industry 4.0 is frequently used in research papers that deal with industrial production. There is also a lack of research papers that explain the relationships between Industry 4.0 and suppliers, wholesalers, retailers as well as transportation and warehousing activities. Therefore, the production sector is more appropriate to be discussed in the context of Industry 4.0 than other SCM subsectors. If we further make a search for journal articles and conference papers that contain both keywords "Industry 4.0" and "production" in title we can identify the increase in the number of research papers that are published each year (Figure 2).

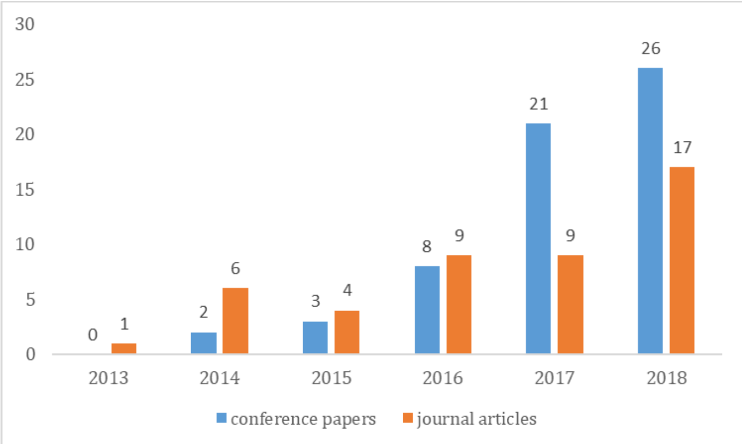

Figure 2. Number of published research papers that contain keywords "Industry 4.0" and "production" in title in the last six years (source: SCOPUS)

Industry 4.0 is particularly important in the context of production planning and control. These contexts share the idea of assigning tasks of production control to "intelligent" objects, such as machines, parts, and products, in order to attain higher flexibility, higher adaptability, and therefore a higher logistics performance (Bendul and Blunck, 2019). Smart production is another concept that relies on Industry 4.0. For example, glass recycling industry empower Industry 4.0 to obtain decision-making information systems and data-driven innovation (Lin, 2018). Another example is intelligent sustainable supplier selection using multi-agent technology. It is found that the previously mentioned approach can help decision-makers inside manufacturing firms to make prompt decisions with less human interactions (Ghadimi et al., 2019).

Industry 4.0 has a potential to be applied in smart transportation and smart warehousing. Smart transportation refers to transformation and redesign of cities' infrastructure. This is particularly related with smart cities, intelligent transport systems and transportation management systems (Schlingensiepen et al., 2016). Smart warehousing refers to efficient data collection, accurate and robust localization, human activity recognition and multi-robot collaboration (Liu et al., 2018).

4. LOGISTICS INDUSTRY 4.0: KEY CHALLENGES

Logistics Industry 4.0 concept has numerous opportunities to transform logistics industry by data-driven insights. The explosion in data size is inevitable today due to necessity for data collection from multiple sources, including autonomous vehicles, robots and other "smart" machines. We have highlighted three key challenges for logistics companies:

1. **Data collection, storage and processing**. With a constant increase in the amount of generated structured and unstructured data, the need for different ways for data storage and processing is also growing. Investments in innovative ICT solutions equipped with sensors are growing with the increase in their additional performances and in their capacity to collect, store and transmit data. New algorithms and models are constantly being developed. Decentralized database for data storage are being replaced with a centralized database systems. However, there is still a lack of regulations for data management. As a result, redundant date is stored in different sectors of the company and additional costs are needed to eliminate them as much as possible.
2. **Data security and lack of standards**. In a complex and highly fragmented logistics industry companies need to share data constantly to keep logistics processes optimized. One of the advantages is to keep the stock level at minimum. However, security issues are major concern for decision makers. A security breach may be defined as an incident in which a logistics company loses sensitive data. Unauthorized access to sensitive data may cause high costs from more than one perspective. For example, production plan may need to be reevaluated and trading partners may lose trust. Security standards and norms are also a condition of achieving a high number of network partners. Without regulations small and medium-sized companies will have to adapt to standards of the large company of which they are a supplier.
3. **Lack of digital strategy**. Along supply chain (and value creation chain as well) data need to be vertically and horizontally integrated and available for all parties involved. Vertical integration refers to the integration of various ICT solutions into a complex information system. Horizontal integration refers to the integration of processes between stakeholders along supply chain. This includes exchanging of data between different sectors (such as supply, production and sales) of several logistics companies along the entire closed-loop supply chain. Therefore, significant institutional and corporate investments need to be implemented to achieve digital supply chain in the back-end.

5. CONCLUSION

Industry 4.0 will reshape the logistics industry in the way that many processes will be digitally transformed. When new technology is introduced in a company resistance of change is almost inevitable due to need for transformation of processes and working habits. Key challenges facing the progress of digital topics in logistics include high costs of technology, lack of trust in data security and lack of regulations and standards. According to authors' opinion the lack of trust in data security will be more difficult to deal with because it introduces risks and uncertainties.

In this paper we have analyzed only a few innovative ICT solutions. There are many other digital topics, such as unmanned aerial vehicles, 3D printing and augmented reality, that also deserve attention. Future research should be directed in their demystification and potential application in logistics processes.

Very important question related with the paradigm Logistics Industry 4.0 is what changes logistics experts, workers and other employees in transportation, distribution and manufacturing companies will be "forced" to accept? According to authors' opinion the changes will primarily be related to necessity to accept new skills and knowledge that was not equally important for logistics experts before. Good computer knowledge (including programming skills) is already inevitable expertise for many logistics experts. And many more will come. Future research should deal with this aspects.

ACKNOWLEDGMENT

The authors acknowledge the support for research project TR 36030, funded by the Ministry of Science and Technological Development of Serbia.

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Part VII STUDENTS' PAPERS

CONSOLIDATION IMPACT ON TRANSPORTATION COSTS AND CO2 EMISSIONS IN GLOBAL SUPPLY CHAIN

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Abstract: *Global supply chains are becoming more complex with an increased number of challenges that logistics executives must deal with, such as distance, delivery time, numerous parties involved with a single international shipment, language and culture barriers. Numerous studies have found that consolidation can improve customer services. Not only that consolidation can improve customer services, but it can also improve market penetration, flow of product return and delivery time, vehicle utilization, flexibility, while reducing fuel consumption, transportation cost and negative environmental impacts. However, the earlier studies have not explored consolidation in terms of transportation costs and the amount of* CO_2 *emissions per unit. Therefore, the major objective of this paper was to investigate the effect of consolidation on transportation costs and* CO_2 *emissions per unit, in order to find out benefits for both customers and logistics providers. The results indicate that an effective consolidation strategy can decrease transportation costs and* CO_2 *emissions per unit, also achieve significant savings for customers and higher profit for logistics provider.*

Keywords: *Consolidation, Global supply chain, Transportation costs,* CO_2 *emissions.*

1. INTRODUCTION

Advances in communications and transportation technologies have led customers to change their buying behavior. Customers are no longer willing to wait for weeks to receive deliveries or pay high shipping fees. Nonetheless, they expect the right product in the right condition to the right place and the right time, at the lowest possible price, despite the long distances.

Recent developments in the field of information and transportation technology have led to a renewed interest in cross-border e-commerce. Continuous increase in convenience of ordering products online has led to customers asking for same-day and next-day delivery at the lowest possible rate. According to the research, 54% of customers consider the speed of delivery and free delivery on purchases over a particular value as the most

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important delivery elements [11]. This has led to more frequent and smaller freight shipments.

Due to the change in the volume and structure of end-user requirements, direct transport, which is most often applied in emergency deliveries with limited delivery time, is not a good solution for small and frequent deliveries in terms of costs and ecology. Moreover, direct transport as a solution engenders a less full vehicle and containers, more empty runs and increased demand for rapid, energy-intensive transport [1]. Therefore, companies need an effective supply chain strategy which is responsive to customer requirements. By contrast, transport represents a process that generates high costs, between 30-40% of the total logistics costs, in addition, it is accompanied by high energy consumption, with a high level of CO_2 emissions [4]. Considering that, the strategy needs to provide higher profit and a good position in the market to the company.

There is one widely accepted strategy that aims to tackle challenges in today's global market. In other words, the strategy to utilize unused capacity inside the vehicles is an advantageous solution that balances quality, costs and transport time needed. Further, higher utilization of transport capacity reduces the number of vehicles on the roads. Moreover, reducing the number of vehicles on the roads leads to reduction of emissions, accidents and other negative impacts of freight transport on the environment. In addition to significant environmental benefits, higher utilization of transport capacity also decreases transportation costs.

Vehicle utilization can be improved by shipment consolidation. Consolidation is a powerful logistics strategy that combines two or more small shipments into an aggregate load, so that a larger quantity can be dispatched on the same vehicle [8], [9].

In recent years, global logistics providers apply various consolidation policies, in order to maximize the utilization of expensive transportation. Nevertheless, it is not always possible to implement this strategy. Successful implementation of the strategy depends upon the characteristics of the goods, flow size, frequency, shipment size, departure and destination region [1].

Previous studies have focused on different models of consolidation and its benefits. In order to explore the potential cost-saving for customers and higher profit opportunities for logistics provider, this paper will focus on the effect of consolidation on transportation costs and CO_2 emissions per unit. The aim of this paper is to investigate whether consolidation can decrease transportation cost and CO_2 emissions per unit.

2. LITERATURE REVIEW

The concept of consolidation is not the creation of state-of-the-art technology. As a solution for more optimal vehicle capacity utilization, it is known for hundreds of years. A considerable amount of literature about consolidation has been published. These studies focused on different forms, policies, models and results of consolidation.

Hall (1987) introduced three forms of consolidation: inventory consolidation, vehicle consolidation and terminal consolidation. The simplest form is inventory consolidation, defined as a process which involves accumulating items produced at different times, in order to transport them as one large shipment. Vehicle consolidation implies loading and unloading items at different origin and destinations. This form of consolidation is used, for instance, in loop distribution and milk run. Loop distribution means that goods are collected and distributed by fixed routes. Milk rounds refer to a smaller vehicle that collects small parties of goods along a fixed transport route to transport it to a terminal where the goods are consolidated to bigger shipments. (Jonsson & Mattsson, 2005). Similar to vehicle consolidation is terminal consolidation which involves bringing goods from different origins to a terminal where the goods are sorted, loaded onto new vehicles and then dispatched to different destination according to different shipment release policies [1].

Furthermore, Hall (1987) presented four freight consolidation policies: one-terminal-closest, two-terminal-closest, one-terminal-best-nearby and two-terminal-best-nearby. One-terminal and two-terminal routing implies that each shipment must go through exactly one and two terminals, respectively before going to the destination. The author asserted that one-terminal routing strategy is not only suitable for cases involving a low number of origins and destinations, but also in cases when travel time is an issue. On the other hand, for the two-terminal routing, both the number of origins and destinations should be large [5].

The closest routing requires that the shipment is served by the terminal closest to the origin or the destination, while each origin and destination is served by exactly one terminal. Moreover, the closest routing is appropriate to use when the shipment is small and the destination and the origin are close to each other. The term 'best-nearby' indicates that the shipment is loaded from any terminal that is closest to the destination. According to the definition above, the best-nearby is appropriate when the shipment is large and the origin and the destination are far apart. The results of this study indicate that the higher shipment volume increases the number of terminals. Furthermore, when the number of terminals increases, the average distance will decline. Therefore, the average distance is lower when one-terminal routing strategy, rather than two-terminal routing is implemented. Finally, the average distance in best-nearby routing is shorter than in closest routing approach. On the other hand, trade-offs are necessary when reducing travel time by adding terminals, changing from two-terminal routing to one-terminal routing, or shifting from closest routing to best-nearby routing [5].

They also found that terminal ownership, cost of operation, and the number of vehicles and routes may increase when new terminals are added. Further, switching to one-terminal routing may require additional vehicle routes, decreased delivery frequency, and deceased load sizes. Thus, changing to best-nearby routing may require additional delivery routes, decreased delivery frequency, and deceased load sizes. In other words, appropriate freight consolidation policies are dependent on the business operation and policies of each firm.

According to Min (1996), there are three different consolidation methods: spatial, product and temporal consolidation. The spatial method concerns selecting consolidation points and assigning the product supplying points to the consolidation points. Temporal consolidation refers to aggregating shipments over time, until the moment when optimal utilization of vehicle capacity is reached and is then transported. Green departure and Fixed distribution days are examples of approaches based on this consolidation method [5].

Cetinkaya (2004) emphasized the difference between pure and integrated policies of freight consolidation. Integrated policy combines inventory and shipping decisions when applying the consolidation strategies. The author proposed three integrated policies of freight consolidation: time-based, where planned shipments are accumulated during a fixed-length period, quantity-based, where weight or volume limits stop the accumulation process and hybrid, or time-and-quantity, consolidation policy as a combination of the first two, where the accumulation process stops as soon as one of limits mentioned above is reached [5].

Cetinkaya and Bookbinder (2003) developed stochastic models for the dispatch of consolidated shipments and derive the optimal solutions under two dispatch policies and two carriers, respectively. One dispatch policy is quantity-based policy where weight limits stop the accumulation process, the other one is time-based policy. Two carriers consist of private and commercial carrier. The authors employed renewal theory in their model to obtain the optimal target weight or the optimal cycle length by minimizing the total cost including transportation cost and inventory cost.

According to key results for private carriage, the expected dispatch quantity under time-based policy is larger than the optimal critical weight. Nevertheless, it is smaller than the mean load dispatched under the quantity-based policy. Furthermore, quantity-based policy has a mean cycle length longer than that of the corresponding optimal time-based policy. Additionally, the time-based policy offers superior service to customers [10].

Crainic et al. (2009) introduced the concept of proactive order consolidation in the global retail supply chain. Consolidation concerns physical flows once movements are already decided, on the contrary, the aim of proactive order consolidation is to effectively group the orders before they are communicated to suppliers, in such a way that the total costs of transportation and inventory of the firm is minimized. A one-dimensional bin packing model is used to group the orders and a simulation approach is developed to compare proactive order consolidation strategies with a full-container ordering strategy. They came to the conclusion that an order consolidation strategy could save substantial costs on inventory and transportation. The results revealed that proactive order consolidation policy is the most favorable policy, which achieves 4.6 percent cost savings over the less than container load (LCL) ordering policy, and 7.5 percent savings over the full container load (FCL) ordering policy even though it has more ordering costs. In addition, the results also imply a FCL ordering policy is not appropriate for slow moving products. What is more, proactive order allows wholesalers to give their 3PL partners better information earlier, regarding the numbers and types of containers required in future period [5].

Considering that the information required to realize cargo consolidation has not been explored too much Wu (2013) created an analytical model to investigate the cost performance of cargo consolidation. The cost model consists of four scenarios and one general case. Simplified assumptions are applied in the scenarios, in order to ensure that the cost functions are comparable for the subsequent analysis. On the other hand, as some of the assumptions in these scenarios are overly simplified, a general case is provided to illustrate the costs of cargo consolidation in a more realistic environment where mixed cargo flows are allowed. The results of the study indicate that the load factor of incoming containers and the unit truck cost have the overall largest positive impact on the minimum cost, while the prefixed load factor for the outgoing containers has the largest negative impact on the minimum cost. Another important finding was that although the average cost performance might be the same, the larger uncertainty makes cost control more complicated and less accurate.

Furthermore, the author stated that cargo consolidation is viable when the load factor of incoming containers is low and/or unit truck cost is high. Moreover, the author concluded that the accuracy of information on container load factor has added value in reducing the operational cost, when applying cargo consolidation. What is more, a larger penalty cost helps to keep the best barge departure time within the planning horizon, as it counteracts the benefits brought by cargo consolidation and barge shipment [10].

Surveys such as that conducted by Mesa-Arango and Ukkusuri (2013) have shown that consolidation can improve economic performance if shipments are consolidated inside vehicles. The authors investigated benefits of in-vehicle consolidation in less-than-truckload freight transportation operations and provides insights on the competitiveness and challenges associated with the development of consolidated bids. Consolidated bids are constructed using a multi-commodity one-to-one pickup-and-delivery vehicle routing problem that is solved using a branch-and-price algorithm. The results of numerical experiment showed that non-consolidated bids are dominated by consolidated bids. This finding implies that this type of operation can increase the likelihood of a carrier to win auctioned lanes, while increasing its profit margins over non-consolidated bids, and keeping the reported benefits that combinatorial auctions represent for shippers. The most interesting finding was that the cost of serving a bundle with in-vehicle consolidation is always less than or equal to the cost of serving it with direct shipments. Therefore, LTL carriers can submit bids with prices that are less than or equal to the costs of TL carriers for the same bundles and getting profits. In contrast, TL carriers could just reach the breakeven point [6].

The authors highlighted that this strategy only covers in-vehicle consolidation. In other words, this strategy does not apply for typical LTL firms where shipments are consolidated in facilities that are strategically located over the transportation network, for instance, terminals, or hubs. Since LTL shipments that are consolidated in facilities are associated with high transportation times, which is not beneficial for shippers/commodities with high value of time, differentiating these two types of consolidation is important [6].

Indeed, combining several orders into one shipment can reduce the total shipping costs. On the other hand, waiting to consolidate current orders with some future ones may require expedited shipping, thus, increasing the costs. Wei, Jasin and Kapuscinski (2017) studied the optimal consolidation policy, focusing on the trade-off between economies of scale (combining multiple orders) and expedited shipping costs (shorter delivery window). The authors demonstrated that the optimal policy can be characterized by a sequence of time dependent thresholds with only fixed cost, whether all orders are shipped from the same warehouse. The optimal policy with two warehouses and overlapping availability of products is complex, in general. Despite the complexity of the actual optimal consolidation policy, sellers can apply the two simple heuristic policies the authors proposed to get near-optimal performance in various cases. The study highlights that the optimal policy in the simplest symmetric case, can be characterized by six non-linear boundaries in three-dimensional space. In two-warehouse case with asymmetric fixed costs, the authors proved that heuristics that replace the six boundaries with no more than three constant thresholds, perform very well in most of numerically tested cases. Besides that, the difficulty of analysis increases with both fixed cost and variable cost [3].

3. PROBLEM FORMULATION

This section presents the mathematical formulation to identify the benefits of consolidation to customers and logistics providers. The focus is on transportation costs and CO_2 emissions per unit.

In this paper, three scenarios will be analyzed in order to investigate the difference in transportation costs and CO_2 emissions per unit. All three scenarios considered the shipment consolidation in the terminal where different shipments are collected and then transported together in one vehicle to end-customer. The difference between the scenarios is the load factor which increases with the number of the shipment consolidated and transported in the same vehicle (Scania truck). The maximum capacity of the vehicle that was considered in all three scenarios is 40 tonnes.

In scenario 1, 16 tonnes were transported in the vehicle, in other words, the load factor of the vehicle is 40%. In scenario 2 the load factor is 60%, according to 24 tonnes transported in the same vehicle. The load factor in scenario 3 is 100%, which is hard to reach when customers expect fast delivery. The reason for this is the time needed to collect the required quantity of the shipment. However, the purpose of scenario 3 formulation is to identify how transportation costs and CO_2 emissions per unit change in regard to the maximum load factor.

So that we would be able to compare those three scenarios, we choose one shipment of 20 kilos as a unit to analyze its share in transport costs and CO_2 emissions. Therefore, scenarios will be compared according to the shipment share.

3.1 The Effect of Consolidation on transportation costs

The total transport costs in this model are calculated as the sum of the fixed and variable costs. Fixed costs include the cost of depreciation and maintenance of the vehicle, personal income, administration, insurance and information systems, as these costs do not change with the change in the degree of exploitation. In all three scenarios, fixed costs are 339 € per vehicle. Variable costs are fuel costs that are calculated on the basis of total fuel consumption and fuel prices.

The ratio between degrees and fuel consumption is shown in equation 1. The FC equation represents the fuel consumption for transporting a particular load to the vehicle, and FCpr and FCpu the fuel consumption when the vehicle is empty and when it is full [2].

$$FC = FCpr + (FCpu - FCpr) * LF \tag{1}$$

Based on this equation, it can be concluded that fuel consumption does not increase linearly with the increase in the amount of cargo being transported. If the fuel consumption is unknown, then it could be calculated indirectly based on the total fuel cost and the average fuel price companies may refer to.

When the vehicle is full, the fuel consumption is about 40 l/100 km and when the vehicle is empty it is about 28 l/100 km in all three scenarios (according to the specifications of Scania truck). The transport costs per unit in this model are calculated as a share of the shipment (as explained earlier) in total costs (the sum of fixed and variable costs). The share of the shipment in total costs is proportional to their share in the total freight transported (TKM) measured by tonne-kilometres.

The results of the transportation costs per unit for each scenario are presented in Table 1. According to the results, transportation costs per unit of scenario 1 are the highest with 660 €, then scenario 2 with 445,63 €, while costs of scenario 3 are the lowest with 283,24 € for the same shipment.

Table 1. Transportation costs per unit

Scenario	The load factor	Transportation costs per unit (€)
Scenario 1	40%	660
Scenario 2	60%	445,63
Scenario 3	100%	283,24

Firstly, by comparing scenario 1 and scenario 3, we found that cost-saving is 57% (376,68 €) per unit. In other words, the vehicle that uses the full capacity saves up to 57% of transportation costs per unit compared to a vehicle with the load factor of 40%. Secondly, by comparing scenario 2 and scenario 3, we found that cost-saving is 36,4% (162,39 €) per unit when the vehicle is full. Finally, by comparing scenario 1 and scenario 2, cost-saving is 32,47% (214,28 €) per unit when the load factor increases from 40% to 60%.

3.2 The Effect of Consolidation on CO_2 emissions

There are a number of methods used to calculate the amount of carbon dioxide emissions (CO_2 emissions) emitted in freight transport. The calculation of CO_2 emissions from transportation essentially is based on the weight of the load, type of the vehicle and fuel used and the distance.

The model presented in this paper is calculated using the following formula:

$$CO_2\ emissions = EF * \frac{FC}{LF*CAP} * TKM \quad (2)$$

Where

- EF is the emission factor (in kg CO2/litre);
- FC is the fuel consumption (litre per km);
- CAP is the maximum transport capacity
- TKM is the freight transported (tonne-kilometres) [7].

The formula for calculating the emissions in this model is obtained on the basis of the fact that it represents the sum of the total distance performed by vehicle on a certain period (KM), the fuel consumption (VC) and the emission factor (EF) [7].

$$CO_2 emissions = EF * FC * KM \quad (3)$$

The emission factor depends on type of the fuel. The vehicle used for this paper uses diesel, therefore emission factor is 2,7 kg CO2/litre [12].

The load factor (LF) is expressed as a percentage of capacity in tonnes. Equation (4) is used to define the load factor.

$$LF = TON/CAP = (TKM/KM)/CAP \quad (4)$$

Furthermore, equation (5) presents the average load (TON), in tonnes, as a product of the load factor and the maximum transport capacity.

$$TON = LF * CAP \quad (5)$$

Moreover, the total distance performed by vehicle on a certain period (KM) is expressed using equation (4) and equation (5) as

$$KM = \frac{TKM}{TON} \quad (6)$$

What is more, using equation (5) and equation (6) KM is expressed as

$$KM = \frac{TKM}{LF*CAP} \quad (7)$$

Finally, equation (7) and equation (3) can be used to derive equation (2).

Table 2. illustrates the results of the CO_2 emissions per unit for each scenario. According to the results, CO_2 emissions per unit of scenario 1 are the highest with 0,238 kgCO_2, then scenario 2 with 0,166 kgCO_2, while costs of scenario 3 are the lowest with 0,135 kgCO_2 for the same shipment.

Table 2. CO_2 emissions per unit

Scenario	The load factor	CO_2 emissions per unit (kgCO_2)
Scenario 1	40%	0,238
Scenario 2	60%	0,166
Scenario 3	100%	0,135

Furthermore, by comparing scenario 1 and scenario 3, we found that the vehicle that uses the full capacity emit up to 43% (0,103 kgCO_2) less CO_2 costs per unit than the vehicle with the load factor of 40%. Moreover, by comparing scenario 2 and scenario 3, we found that that the vehicle that uses the full capacity emit up to 30% (0,072 kgCO_2) less CO_2 costs per unit than the vehicle with the load factor of 60%. Finally, by comparing scenario 1 and scenario 2, we found that that the vehicle with the load factor of 60% emit up to 18,7% (0,031 kgCO_2) less CO_2 emissions per unit than the vehicle with the load factor of 40%.

4. CONCLUSION

This paper is the first step towards enhancing our understanding of the consolidation effect on the global supply chain. Global supply chain became more complex and more challenging. Thus, logistics executives must develop an effective supply chain strategy. Consolidation is a widely accepted strategy that is responsive to customer higher requirements and also provides a higher profit to the company. This strategy improves vehicle utilization that on the other hand reduces the number of vehicles on the roads.

It is important to highlight that in this paper only transportation costs and CO2 emissions were analyzed. In order to analyze the difference in transportation costs and CO2 emissions per unit, three scenarios were compared. Three scenarios considered the shipment consolidation in the terminal where different shipments are collected and then transported together in one vehicle to end-customer, with different load factor. The unit that was used for comparison is 20 kilos shipment.

The numerical results show that consolidation is beneficial for both customers and logistics providers as it decreases transportation costs and negative environmental impacts. As a result of increasing the load factor, costs per unit decrease. Considering that, combining shipments for improving vehicle utilization is lowering overall transportation costs. Reason for this is that fixed costs in transportation are spread for more kilometers and kilos. In addition, improving the vehicle utilization that leads to reducing the number of vehicles decrease CO2 emissions per unit, and the reason for this is that CO2 emissions are spread for more shipments.

In spite of the fact that only transportation costs and CO2 emissions per unit were analyzed, the findings will serve as a base for the future master thesis. The future master thesis will focus on additional costs per unit that increase with consolidation in order to compare them with the savings that were found in this paper.

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THE TENDER FOR PROCUREMENT OF LOGISTICS SERVICES AND DEVELOPMENT OF LOGISTIC PARTNERSHIP

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Abstract: *The logistics partnership is a very current topic and most of the companies are trying to achieve a good partnership with the other party so that everyone would benefit from it. The selection criteria are multiple and the process of evaluating them is extremely long and complex. The tender process can be viewed from two different perspectives: foreign companies that have a need for a logistics service or companies that offer their services. In this paper, the focus is on a company that is interested in selling its logistics service to a customer. The tender procedure is presented in the logistic company offering its service. All steps in the realization of the concrete tender are described in detail. The aim was to point out the procedures that the company, as an interested party that has an interest in concluding a contract with the buyer, should take.*

Keywords*: tender, logistics services, logistic partnership.*

1. INRODUCTION

Today is the era of modern logistics and continuous contracting, partnership and communication. Companies compete by reducing costs and improving service levels in order to create added value in the supply chain. In order for this to succeed, the companies must achieve a high level of cooperation and trust with their partners. This refers to companies that aim to find long – term partners with whom they will cooperate in the field of logistics. Improving cooperation between business partners increases the efficiency of transport networks and enables fast exchange of information, which increases the success of business and market success. An excellent choice of supplier and a history of relationships can positively affect the quality of the service. Since there is the lack of research in the existing literature dealing with the selection of suppliers, meeting, history of relations, logistics cooperation, companies are more inclined to decide on the conclusion of long – term business relationships. The two most important factors affecting the decision with which to enter into a contract may include earlier experience or recommendations and positive opinions about a particular company, and the second factor are some operational options such as geographical coverage, response speed or

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providing value – added service. One way to find a good business partner is a tender. Tenders are often used in state institutions, but today they are often present when it comes to purchasing logistics service most often from 3PL providers.

The paper is conceived so that it consists of three entities. At first it is an introduction to the work itself and explanations of certain terms. In the second part, the focus is on logistic partnership and realization of logistical partnership relations. The second part describes the tenders as one of the ways to establish partnership relation. In third part, there is an example of a tender conducted in a logistics company. The tender procedure is presented from the aspect of the logistical service provider.

2. LOGISTICS RELATIONSHIP AND TENDERS

This part of the paper discusses logistic partnership and tenders as one of the ways to achieve long – term partnerships. Tenders are frequent occurrences in business today and are applied in logistics mostly in the procurement of logistics services.

Partnership can be defined as a relationship characterized by openness and trust where risks, rewards, and expenses are shared between the two sides (Aharonovitz M, Vieira J, Suyama S, 2018). Companies operate with supply chain partners to manage internal and external organizational processes in order to optimize resource utilization, share information, risks, and rewards in order to improve performance and profit generation. In addition, in cooperation of two or more independent companies, they are working on planning and carrying out operations in the supply chain, which is a better and more efficient way than an independent one. "The Logistic Partnership was created in 1980 as an important tool for improving the efficiency of the supply chain." (Maloni and Carter, 2006). In the logistics partnership, activities include joint planning and information exchange, and the focus on strategic planning is smaller. These logistical activities include all services provided to users, operations related to planning and demand forecasting, mode of transport, vehicle types, order realization, warehouse services, inventory tracking, packing services and return logistics. Logistic partnership can be viewed from three different aspects: strategic partnership, tactical partnership and logistic partnership based on interpersonal elements. Strategic Logistic Partnership is a relationship that is based on the fact that both company leaders are involved in projects that are related to long – term decisions. The Tactical Partnership includes common information related to the sale of logistics services, plans, communication, existing information sharing technology, the formation of teams to work on projects, actions to address unforeseen situations. Partnership based on interpersonal elements is based on open communication and shared values that increase trust. Research shows that trust and dedication lead to improved performance of both side (Aharonovith M, Vieira J, Suyama S, 2018).

Tenders are used in the procurement of logistics services. Procurement of services refers to all activities necessary to obtain products from suppliers to end users, including purchasing, transport and quality control. Terms of supply chain management are often used in connection with procurement (Taneli L.). The current market insecurity affects the company by increasing its level of flexibility to satisfy the client. However, in today's environment, the time is very dynamic and requires companies to constantly make efforts to strengthen and position themselves on the market, while ensuring that the level of flexibility is at a high level. The companies can no longer be limited to their own resources, but they must seek suppliers with specific capabilities that meet their needs and help them achieve a high level of customer satisfaction. The most common are 3PL providers who take certain segments of the supply chain and perform certain services. In order for the company to achieve successful cooperation, in the beginning it has to select an adequate supplier. The choice of suppliers is not easy, as many criteria have to be taken into account.

The need for procurement of logistics services is growing and comes from the decision to sell the services to the logistics companies, which is the key decision. One of the ways to find a good and reliable partner is tendering. Tender is a procedure in which the suppliers are selected on a competitive basis. He is a single process where the customer of a logistics service has the need for it and it defines its requirement. The buyer presents his request to the potential partners who are mutually competitive. Tenders made out in order to save the costs for both parties so real business partners are needed to do the business. However, there is no tender procedure that is defined and universal for all (Suominen M., 2018). Each tender varies depending on the type of service, needs and requirements of the buyer (http://www.mcentar.rs/faq/21.ht). The second part of the paper presents a practical example of a tender that was realized in a company in Serbia.

The key part of each tender is the choice of suppliers. The choice of suppliers is a process that is mostly long – lasting and requires the greatest attention. In other words, this is the process of making multi – criteria decisions. The multi – criteria decision is based on a variety of criteria on the basis of which suppliers are ranked. Fairness, reliability, price, service offered, tender quality, technology and reaction to changes are some criteria that are most commonly used in making decisions. In addition to these criteria, the reputation of the company, culture, delivery speed, transport security, global network, innovation, quality, relationship orientation, reliable performance, support, capacity and flexibility in the supply chain are also important. Companies that try to keep these criteria at a high level have predispositions to maintain strong ties with their business partners and to maintain their high performance (Aharonovitz M, Vieira J, Suyama S, 2018).

3. ANALYSIS OF THE TENDER PROCEDURE

This section will show one complete tender procedure. It is about a logistic company that offers its service and sales through tenders. The description of the tender is defined on the basis of the real case from practice.

There are two types of tenders in a company: local and multinational. The multinational tender is realized by sending a request for a bid to the central tender management team. The team, based on the user's need for service, forward the request to a particular branch office in a particular country. The local tender implies that a request for a bid from a client is sent directly to the local branch office. This request is sent via e – mail in the form of excel tables directly to the person responsible for the sale of services in the company or the person in charge of tenders in the logistics sector. After receiving the excel table, the procedure is in line with the multinational tender procedure.

The following section describes the detailed procedure of a multinational tender. The example shows the successful tender procedure for which the company received the job. The process consists of six steps (Figure 1):

1. Indication of the buyer – tender announcement;

2. Downloading the request and preparing the offer;
3. Acceptance of offers, consideration and selection criteria;
4. Obtaining work and activities after the completion of the tender;
5. Negotiation, service delivery and control;
6. Activities after the completion of service delivery.

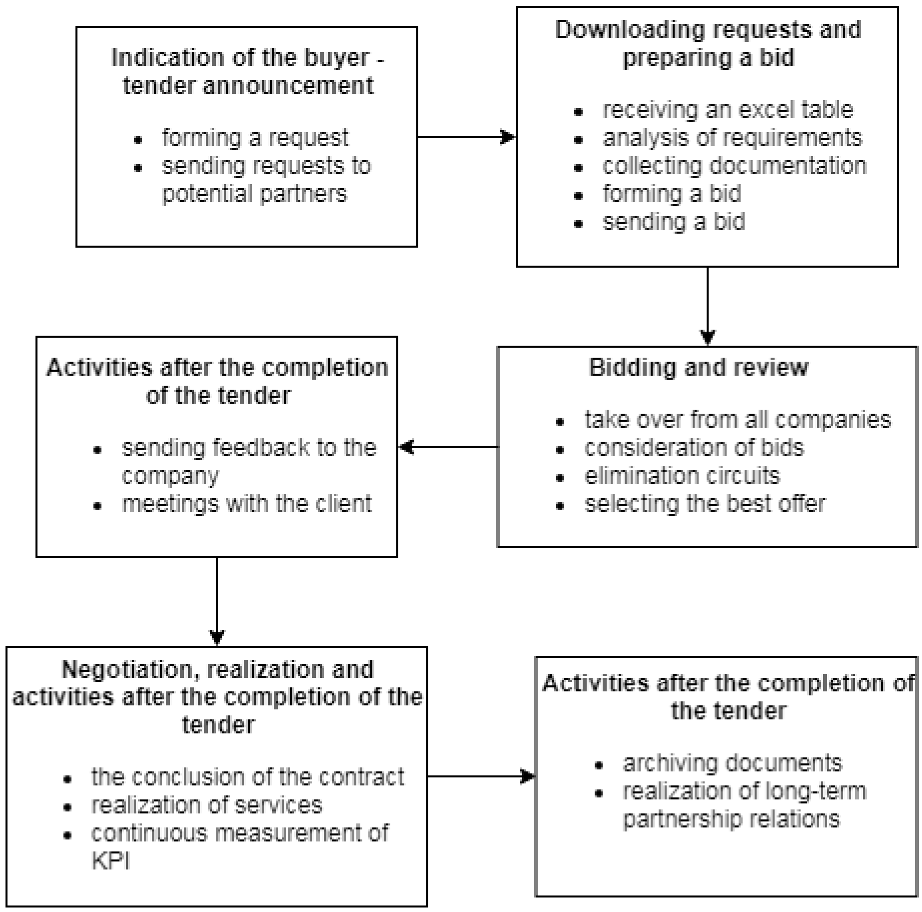

Figure 1. Procedure for the realization of the tender

Indication of the buyer – tender announcement is the first step in the entire tender procedure. A tender occurs as a result of the customer's need for a particular type of service for a defined period of time. The buyer defines his request, conditions and deadlines. He is obliged to provide clear and detailed descriptions of what he expects from the service provider. As it is the multinational tender, the user using the appropriate IT tools puts his request on the platform. The deadline for submission of bids must be accurately and precisely defined. The service provider is obliged to notify the supplier and which documents and certificates must be attached to the offer, as well as a detailed description expected from the supplier.

3.1 Download requests and prepare the offer.

The central management team accesses the platform and takes over the user's request. Since the company owns branches around the world, the central tender management team, based on the location where the service will be provided, is obliged to submit the request to one of the affiliates in the world. The team from the local branch office takes over the request. This request is displayed as an excel table. In this table there is a part that is filled in by the company and it is necessary to enter the price charged for the requested service. In addition to the price sometimes, it is necessary to write some additional solution or proposal. Entering data and prices into the table is followed by obtaining the documentation required by the client. It's mostly in question some certificate (depending on the type of the goods) and the ownership structure of the company. Once the offer is ready, feedback is sent to the buyer.

3.2 Receipt and evaluation of the offer.

The offer is placed again on the platform, and the client removes the platform from the offer. The tender closes exactly when it is defined. All bids sent after the expiration of the deadline will not be considered. The buyer receives more offers from different suppliers. Thereafter, consideration is given to access and decision making. Mostly tenders are cyclical and there are several selection and elimination circles. After a certain number of circles, the buyer decides on the supplier whose offer he accepts, that is, the supplier that he considers satisfies his requirements. Criteria for choosing a supplier can be multiple, but one of the main criteria is reliability. In order to have reliability, many buyers are willing to pay higher service costs. In addition to reliability, the client's experience can be an important criterion. If the client has already cooperated with the company that had applied for the tender and has a positive experience, it is more likely that this company will be selected. The next important criterion is the name of the company, a company that is known as a reliable partner in the market has more chances to win a tender. The quality of the tender process is also an important criterion, as the company strives to process the request in a more detailed way and in that way achieve the trust of its client.

3.3 Getting work and activities after the end of the tender.

After several rounds, the buyer decides which bid he accepts. The company is selected and electronically or by telephone is informed that it has received the tender. After all, there is an agreement and more detailed consideration of the user's request. The team responsible for the specific tender analyzes the user's request. The mistakes and difficulties that later occur most often are due to poor understanding of the request, imprecisely defining the request, the responsibilities of both parties defined by the delivery parties, specifics of goods and the like. After the tender, and before the beginning of the realization, the company team meets with the user to clarify every doubt that can later be a problem. If during the conversation with the client it is determined that the request was not well defined or that it was ambiguous, the company has the right to cancel the tender and refuse the cooperation.

3.4 Negotiation, service delivery and control.

After the meeting with the client has been completed and after all the dilemmas have been clarified, it is time for the negotiation. However, contracts are not always necessary, that is, each tender does not have a contract. Mostly tenders are called in order for buyers to find their business partner with whom they will later cooperate. On the other hand, there are tenders that have contracts with them for a certain period of time. The length of the contract depends on the type of the service (1 year, 1+1 year). The next step is the realization of extensions. The company does not accept payment of any penalties in case of delay or other irregularities. Instead, the company has KIPs that must be at the appropriate level. As a responsible business associate, the company performs KPI measurements during service delivery. Performance indicators in the realization of the service must be 95% or more. If this percentage is reduced even by 0.01% the company calls it s client, informs that KPI has dropped and agreement with him finds a solution and returns the quality of service to higher level.

Activities after completion of service delivery. The service is performed, requests and expectations of the client are met and both sides are satisfied. In this case, the company proved to be a responsible and reliable partner. The users experience with the company is good and when choosing the next tender he will have a better opinion of the company which will separate it from the rest. The documentation which follows the tender from the very beginning until the end, the company keeps in the archive, because sometimes in the future for the realization of the next tender some historical data will be necessary. In this way, one tender is finished and concluded.

4. CONCLUSION

The goal of the tender is for a company to primarily earn profit by providing it s services to the client. In addition, long – term partnerships can be achieved in this way. If the client is satisfied with the engagement of the company, next time he will not call tender but will immediately contact and engage the company. However, not all customers have the main motive to achieve the logistic partnerships. Many users call the tenders for benchmarking, in this way they learn from the leaders on the market and get new ideas and solutions that they later apply to their business. Also, the motive for inviting tenders can be an insight into the prices on the market.

In order to maximize profit and increase business efficiency, the company must be left to negotiating, contracting and partnerships with various clients, suppliers, distributors, freight forwarders. The company strives to increase it is own network of clients and maximize the number of users, and in order to achieve this it has to enable negotiation with it s clients and partners on a global level. It is very important that trends are monitored in order to achieve as much competitiveness as possible. Companies are in a position to satisfy the user, while at the same time earning as much income as possible. The logistics partnership is based on the confidence of the two sides. A successful company should have a good reputation and recognition on the market. In addition to the reliability and security that companies offer to their business partners, technology and continuous innovation, continuous investment in information technology and the possession of professional staff are also of great importance.

The choice of suppliers of logistics services is the hardest part of the deal when it comes to the procurement of logistics services, because it requires a lot of effort to choose a supplier who will manage to meet all the requirements of the customer. The customer of the logistics service must define the criteria that the supplier must possess. Today, the competition market is extremely large and it is not easy to choose an adequate partner. If a supplier is found the customer that meets all the requirements and needs of the customer, it is very important to keep it. The high frequency of regular meetings, trainings and visits can increase communication between logistics partners and provide the opportunity to avoid future problems and identify areas for improvement

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LEAN APPROACH FOR IMPROVING PRODUCT DISTRIBUTION PROCESS

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Abstract: *From the customer's perspective, distribution represents a very important phase of the supply chain. By realizing logistic processes and activities, the value that is delivered to the customer is created, while on the other hand, significant costs are generated. Since it is very difficult in practice to increase quality and value at the same time, companies are striving towards newer solutions and their applications. This paper analyzes the approach for calculating distribution costs, as well as the possibility of applying the Lean distribution concept in order to eliminate waste and create value for customers.*

Keywords*: lean distribution, logistics value, logistics costs, distribution process*

1. INTRODUCTION

Nowadays, managing logistics and distribution activities for companies may be a major challenge. With the ever-increasing globalization of markets, demands for efficient delivery of goods are growing, which means more specific services required by the customers. In order to maintain a stable position in the market and achieve profit, it is necessary to continuously plan and optimize the distribution process. Distribution logistics provides spatial and temporal transformation of goods through a structured distribution network, which can be very complex. There are various approaches to the improvement and optimization of the distribution process where the goal is to achieve a higher quality and value for consumers on the one hand, and a lower cost on the other. Distribution is an area in which significant savings can be achieved as well as waste reduction. Nowadays, logistics uses various approaches to improve process and waste disposal. In this domain, the Lean concept is emphasized, which is defined as an approach, intended for the overall improvement and improvement of the process within an organization, with a continuous reduction of waste and refers to the strategic and operational decision making level. Lean also found its application in supply chains, with special emphasis on distribution and improvement of the process by creating values and eliminating waste. Muraira et al. (2014) emphasized that customer satisfaction and understanding of the market was very important for defining the supply chain strategy. They also pointed out that the dynamics of today's industry have influenced the design of the supply chain with the emphasis on achieving a higher level of customer service, the

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quality of products and services, the costs as well as the flexibility of product offering to meet customer requirements. The subject of the research paper is devoted to the analysis of the possibility of optimizing the distribution process using the Lean concept. The main goal is to determine the overall relevant distribution processes whose optimization may affect the creation of value for the customers and thus to reduce logistics costs.

The paper is organized as follows: the first part refers to the structure and main characteristics of the distribution system; the creation of values through the distribution process is shown in the second part; in the third part, costs and wastes in the distribution were analyzed; the concept of Lean distribution is presented in the fourth part of the paper.

2. STRUCTURE AND MAIN CHARACTERISTICS OF THE DISTRIBUTION SYSTEM

For the customer, the most important phase of the supply chain is distribution. For this reason, it is necessary to pay special attention to the distribution system functionality, because it represents a direct connection with the customer, which, based on the observation of this process, creates the experience of the entire supply chain. When looking at the structure of the distribution network, in terms of the number of elements in the hierarchical structure, a decentralized and centralized distribution network model may be distinguished. The decentralized structure between the shipping warehouse and the end-user implies several levels, where different warehouse and distribution centers are located. For this reason, this structure is also called the hierarchical distribution structure. In the case of a centralized model, there are no intermediate warehouses between the dispatch point and the end-user (delivery is realized by one - central warehouse). The distribution system can be observed as a distribution system in a wider sense (from the production of raw material to retail) or as a distribution system in the narrow sense (from the production of finished goods to retail), as shown in Figure 1.

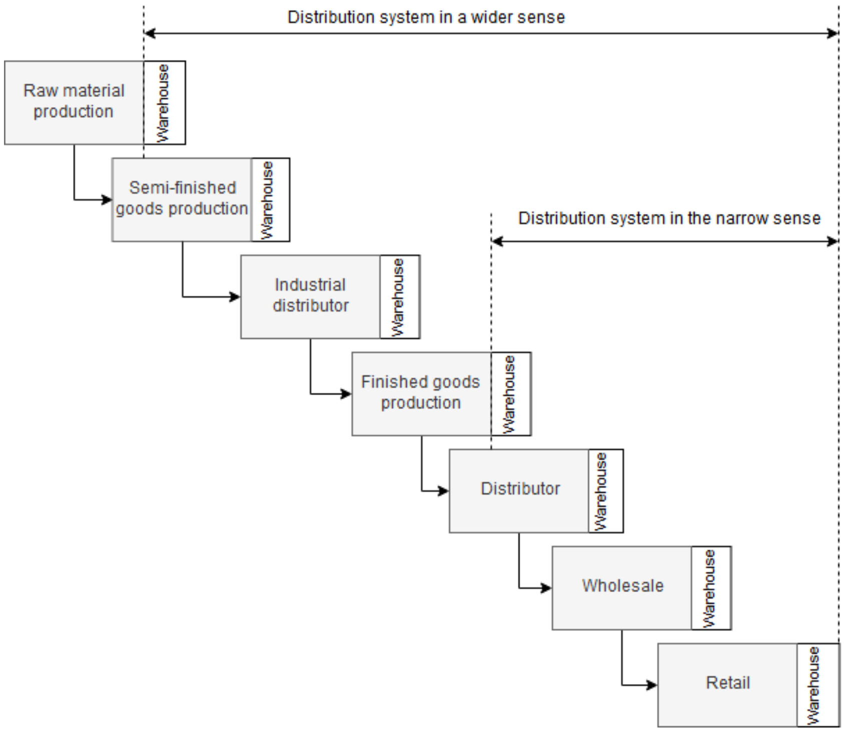

Figure 1. Distribution system (two perpectives) [2]

Therefore, the process of product distribution is an area where value is created for customers, while on the other hand it causes significant costs. For this reason, in this area, it is possible to achieve savings and eliminate waste. Of course, improvements can not be made without the use of certain expertise and approaches and attention has to be paid to the choice of an effective concept depending on the specific environment.

3. CREATING VALUE THROUGH THE DISTRIBUTION PROCESS

Huge market changes, new technologies and strong competition have led to the emergence of growing customer's demands in terms of quality of service. Specific customer's requirements have led to the fact that products and services require a certain level of customization. On the contrary, companies are trying to meet all the requirements of the customers at affordable costs. This requires the creation and improvement of value that is delivered to customers. Logistics and supply chain have become areas where products are being prepared for sale in logistics and distribution centers and where the value is created (Kilibarda et al., 2013).

A product or service is a value for the customer when provides what the user wants, expects and appreciates. Supply chain becomes a value chain when all participants strive to provide value to their direct and indirect customers, but also to eliminate wastes through the delivery system. Finally, the value delivered through the value chain is reflected as a profitability for all participants in the value chain. The value is actually represented as a ratio between "what the customer gets" and "how much it costs."

Value in logistics can be created through the realization of: standard logistics services, additional logistics services and specific logistics solutions (Kilibarda et al., 2013). The product has one value when it is at the consumer's place and the other when it is in the factory warehouse and this can be presented as a spatial value. Customers often require a product or service at a precise time and this can be presented as a time value. For example, the delivery of daily newspapers is required early in the morning and then has a certain value for the user. On the contrary, if daily newspapers are delivered in the evening, the value for the user practically does not exist. Spatial and time value are realized by the implementation of standard logistics services (transport, storage, transhipment). VAL (Value Added Logistics) services are related to the finalization of products by the realization packaging, assembly, installation, processing, marking, etc. These services relate to qualitative and quantitative changes on products that are conditioned by user requirements. Specific logistic solutions relate to: reduction of operational costs, improving the return on investments, increase of revenues and market share, improvement of flexibility and speed of logistics process implementation, improving the visibility of logistics processes, etc.

4. WASTES AND COSTS IN DISTRIBUTION

Nowadays, identification and cost optimization are a very important aspect of business, especially in logistics and distribution. Improving logistic processes and activities requires precise data of logistics costs. For this purpose, where the goal is to diversify the costs of logistics activities, a various approaches and tools are used. Distribution process is realized from the producer to the consumers through several logistics systems. Within each system, it is possible to identify a complex set of logistics processes and activities, which can be classified into six basic groups, such as: ordering, packaging, transshipment, transport, warehousing and inventory.

In order to calculate the logistic costs for each process individually, various techniques and models are applied in logistics. One such model is proposed by Kilibarda (2016), where, at first, the total cost of managing logistics systems is calculated, and then assigned to logistic activities. In the following part, the mentioned model was analyzed.

Ordering process includes the time that elapses from the receipt of the customer's order until the delivery of goods and the renewal of the customer's inventory. Ordering is an initial activity that dictates the structure of all other logistics activities and processes. The costs of ordering are affected by affordable space and personnel, assets, equipment, consumables, mincing materials etc. On the other hand, ordering costs depend on the amount of goods being ordered. Ordering costs may be described as follows:

$$Tpo_i = f(Npo_i, T_{upo}, Q_i) \tag{1}$$

where:

Tpo_i – ordering costs of product i; Npo_i – number of orders for the i-th product; Q_i – total flow of the i-th product; T_{upo} – total cost of ordering process.

Any administrative activity is a resource that does not represent a value in the business world. These activities require certain resources and the right information at the right time. Communication technologies such as electronic data interchange and the Internet minimize costs and risks of errors (Goldsby & Martichenko, 2005). To ensure better control and ease of management, many companies turn to technological solutions. Wastes can arise from wrong information, late information, inadequate technology, etc.

The package has a protective, transport, manipulative, storage and information function. The packaging process includes the activities of forming a logistics unit (storage, transshipment, transport). Packaging costs depends on the engagement of labor, resources, machines, space, consumables and can be described as follows:

$$Tpa_i = f(Npo_i,\ Q_i, T_{upo}) \tag{2}$$

where:

Tpa_i - packaging costs of product i; Npo_i - number of packing of i-th product; Q_i - the total quantity of the i-th packing product; T_{upo} - total packaging costs.

Inadequate packaging that does not protect the content is the cause of various damages that can be understood as waste.. Also, waste occurs when companies over-investing in packaging. When designing the packaging, it is necessary to take into consideration the efficiency and in this connection, better use of the container space, vehicle space and storage space. Many companies and entire industries are adopting packages that can be re-used. Also, packaging provides visual control in supply chains (Goldsby & Martichenko, 2005).

Transshipment has a spatial function and it refers to the loading of goods, the change of the type of transport and the unloading of goods. Transhipment costs arise as a result of the engagement of labor and transhipment manipulative mechanization, applied technology, labor volume, etc. Transshipment costs are in the function of the following factors:

$$Tpr_i = f(Npo_i, Q_i, T_{upo}) \tag{3}$$

where:

Tpr_i - transshipment costs of product i; Npo_i - number of manipulative units of the i-th product; Q_i - total flow of the i-th product; T_{upo} - total transshipment costs.

Transport is one of the most expensive processes in the supply chain. For this reason, freight forwarding and transport companies mainly focus on optimizing transport and reducing the costs of transport activities. Transportation costs can be described as follows:

$$Ttr_i = f(L_i, q_i, Tts, T_{str}, Bis_i, Q_i) \tag{4}$$

where,

Ttr_i - transportation costs of product i; L_i - average distance of transport of i-th products; q_i - average quantity of the i-th product in the transport unit; Tts - average cost of engaging the veichle ; T_{ztr} - common transport costs; Bis_i - the number of deliveries of product i; Q_i - total flow of the i-th product.

If the transport service is purchased in the market then Tts represents the price of transport, and when it comes to own transport, it is necessary to determine the total costs for the given asset.

Transport generates the highest logistics costs. In addition to affecting costs, transport is an essential component of delivery time and contributes to variations in the lead time. Transport wastes may occur due to postponement of delivery as a result of congestion in traffic, delays, equipment malfunctions, bad weather conditions, etc. The purpose of the Six Sigma concept in transport is to reduce the average delivery time and reduce variations around that average. Inefficiency and wastes occur as a result of inefficient use of resources. However, many companies do not recognize the possibility of goods consolidation, which can contribute to cost savings and service improvements.

Warehousing process involves several processes that are realized in the warehouse and can be described through three basic processes: inbound process, storing and outbound process. Warehousing costs depend on the intensity of the input and output operations, engaged assets, the administrative activities, the engaged space, etc. Thus, warehousing costs can be described as follows:

$$Tusk_i = f(Nuo_i, Nio_i, Tms, Nd_i, No_i, V_i, Tso, Q_i, Tsadm) \tag{5}$$

where:

$Tusk_i$ - warehousing costs of the product i; Nuo_i - the average number of input operations for the product i; Nio_i - the average number of output operations for the product i; Tms - costs of manipulative assets in the warehouse; Nd_i - average number of deliveries of the i-th product; No_i - the average number of shipments of the i-th product; V_i - the average volume occupied by the product i; Tso - costs of space; Q_i - total flow of the i-th product; Tsadm - the administration costs.

According to Goldsby & Martichenko (2005), it is estimated that more than half of the activities carried out in the warehouse do not add value to products while consuming resources at the same time. It is very likely that the warehouse contains assortments that do not meet the customer's requirements. On the other hand, companies are faced with the question of how much space would be enough to meet the customer requirements. Companies charge customers the storage per square meters that they occupy plus the handling of goods and additional services. It should be kept in mind that there are always fixed costs in the warehouse, while the variable costs are in function of the labor volume. Wastes in the warehouse can arise as a result of inefficient use of space, the use of inadequate technology, etc.

The inventory represent tied up capital and their holding "captures" money that could be used for other investments. The cost of keeping inventories includes the following cost components: capital costs, taxes, insurance taxes, risk costs (outdated inventory, damage, defects, etc.), storage space. The quantity of goods, the value of goods and the time of goods holding in stock have a major influence on inventory costs. Inventory costs can be described as follows:

$$T_{Zi} = f(W_i, C_i, k_s, k_{osg}, Q_i) \tag{6}$$

where:

T_{Zi} - inventory costs of product i; W_i - average quantity of i-th products in stock; C_i -price of the i-th product; k_s - coefficient of tied capital of the i-th in-stock product (interest rate); k_{osg} - coefficient of insurance of the i-th product in stock; k_g - the loss coefficient of the i-th product in stock; Q_i - total flow of the i-th product.

Inventory exist due to the absence of current production and delivery. In this case, companies have to anticipate what users desire, in which quantity and where, i.e. forecasting of requests is carried out. Forecasts are never fully accurate and companies often accumulate stocks that increase costs. Excess inventories then have to be disposed of at a lower price, removed or maintained until consumed. On the other hand, in case of lack of inventory, opportunity costs are being arised. It is necessary to find an optimal level of stock with control of variations and improvement of processes in supply chains, which is the goal of the Six Sigma concept (Goldsby & Martichenko, 2005).

When it comes to waste, knowledge may be the least recognized and least understandable resource in managing any business. It can not be seen or easily quantified, but it is largely a resource. According to Goldsby & Martichenko (2005), lack of knowledge can cause big wastes in companies. In the functions that are most often associated with a business strategy, such as research and development, engineering, marketing and finance, knowledge is at the core of their existence – the knowledge about what buyers will buy, knowing how to create the desired product, knowing how to attract users, etc. Companies should apply formal and informal ways of cultivating knowledge in order to avoid knowledge waste. Waste is created by doubling the efforts of employees in different parts of the company. Therefore, it is necessary to share information, knowledge and vision, both in the company and in the entire supply chain.

5. LEAN DISTRIBUTION

Lean philosophy origins from Toyota (Japan) and was created around the 1970s as a Lean manufacturing. The goal not only was to eliminate wastes and excesses in production, but also to generate value for the customer for which he is ready to pay. As such, it is applied in many industries. The main advantage of Lean's implementation is cost reduction, quality improvement and improved customer service. The concept turned out to be very successful and later became a standard in industries such as automotive, aviation and computer industry (Honda, General Electric, Boeing, Helwett-Packard, IBM, Zara, Amazon, etc.). Lean is actually a philosophy that is based on the six principles: elimination of waste, a broad view, simplicity, continuous improvement, visibility, flexibility. A special emphasis is placed on the elimination of waste, where waste is anything that does not create value (Sanders, 2013).

At the strategic decision-making level, Lean refers to an increase in value, while at the operational level it involves a range of techniques and tools. Some of the most important tools Lean uses are: Kaizen, Pull System or Kanban, Taguchi Method, 5S, JIT (Just-in-time), Poka Yoke, TPM (Total Productive Maintenance).

Lean's concept of distribution emerged as well as its predecessor - Lean Manufacturing, in the automotive industry (Toyota, Japan) as an approach for managing large and complex supply chain networks in order to reduce costs and provide high quality (Vecchiato, 2012).

Lean distribution is essential to improve the logistics process, and has a significant effect on the efficient implementation of the logistic activities, as shown in table 1.

When it comes to customer service, Lean relies on managing all flows in line with customer’s consumption, while traditional approaches are more focused on forecasting. In this case, forecasting is fairly accurate in traditional approaches, while Lean uses the forecast only for long-term planning. In terms of inventory, Lean's advantage is that goods are consolidated at source, so flows are flexible - they can be routed in relation to changing customer requirements. In comparison to traditional approaches, Lean is more focused on customer requirements and therefore on their variable requirements and aims to reduce variability. Regarding transport activities, both traditional approaches and Lean tend to improve efficiency through optimization of transport routes. As costs are one of the biggest problems occurring in logistics, it can be noted that all the concepts that are applied have the aim of reducing costs. When it comes to distribution, Lean is focused on reducing overall costs by comprehensively optimizing the process. As Lean is based on the Pull concept, it means that it is based on customer’s demand, which further means lower level of stock, better communication, precise production and accurate information of customer needs. Thus, companies overcome oscillations and create space for flexibility, all in order to reduce total costs.

Table 1. The influence of lean distribution on logistics dimensions [7]

Dimension	Traditional approach	Lean distribution
Customer Service	Collaborate to forecast	Manage flows as customer consumes
Forecasts	Accurate enough, but should strive to be more accurate	Limited accuracy; use for long-term planning
Inventory	Is an asset and should be close to the customer to meet lead time demands	Consolidate at the source and redirect flow quickly for changing replenishment needs
Variability	Not explicitly used in planning, but measured in operations if Lean and Six Sigma are embraced	Customer demand and supply chain variability used in Lean processes
Transportation	Changing with forecasts and orders; seek to reduce	Replenishment cycle driven; stabilize lanes to reduce
Optimization	Reduce each component of cost while filling forecasted demand	Streamline distribution total costs to replenish actual demand
Assumptions	Forecasts are sufficiently accurate and stable for planning; all cost reductions add to net profit; inventory costs less than labor	*Pull* reduces variation and improves service; only total cost reduction adds to profit; Inventory, handling and storage costs are understated

5. CONCLUSION

Nowadays, companies operate in the market of increasing competition, where it is of huge importance to respond to the demands of customers in order to meet their needs and desires. Efficient realisation of the process requires some time-consuming and resource-intensive efforts. In order to meet customer demands, companies not only use sources inefficiently, but also generate unnecessary costs, which means lower profit and less market share. Distribution process is an area where it is possible to work in order to reduce costs. On the other hand, it is necessary to consider the customer requirements and on that basis, to improve the services.

The complex distribution networks and processes that are implemented within them not only require efficient management, adequate cooperation with the goal of reducing the number of subcontractors, understanding, patience and efforts of employees, but also large investments. Leading global companies efficiently use the Lean concept and its techniques and tools, where for each concept there is an accurate application and goal. Business with low level of inventory has led to enormous changes in business, where the JIT concept plays an important role. The advantages of Lean concept are tremendous, but certain shortcomings can be noticed here as well. Dealing with only one supplier can cause major problems if that same supplier suddenly stops working. Although Lean is originally related to the production process, nowadays, it is successfully applied in all aspects of business. An efficient and effective implementation of this concept requires detailed analysis of processes and environments, a certain amount of time and large investments.

The ability of apply depends on the commitment of management, the knowledge of processes and customers and competitors.

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PERIODIC REPLENISHMENT WITH ZONING: A DISTRIBUTION COMPANY CASE STUDY

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Abstract: *The problem being studied in this paper stems from the requirement to distribute items from the warehouse to the client. Primarily, it was necessary to divide the distribution region to a number of zones, which represents a division of certain territory according to a specific criterion. By zoning these regions, periodic delivery of goods for PTT objects is enabled on certain days of the week. PTT objects are representing points in the region with a specific request for delivery -considering that each zone serves a certain day. The deliveries are divided into three groups: direct deliveries by tractor units, direct deliveries by trucks and small deliveries for milk run delivery. Two approaches were used to solve the routing problem: a heuristic clearing algorithm and a VRP solver. In addition, two zoning approaches were used: two zones with a PTT object balance, and three zones with a pallet balance.*

Keywords*: distribution, zoning, periodic replenishment*

1. INTRODUCTION

Problems of forming routes for vehicles (routing problem) represent a typical operational problem. When routing a vehicle, there is a set of transport requests that have to be performed. It is necessary to know the company's fleet. The task of routing is to determine all the routes to a certain location that vehicles must serve, in order to fulfil transport requirements. It is necessary to know the capacity of vehicles, as well as to try to minimize transport costs and also to respect the time interval for delivery. Different algorithms and methods have been developed for this problem (Vigo, 2014). In this case study, two methods have been applied. The idea of solving an existing problem using these methods is to obtain a good quality solution in the best possible way, and therefore to save money. Prior to routing, it is possible to perform zoning of the distribution region and allocation of days of the week, in which delivery is performed, with the idea of consolidating supplies and using the same vehicle fleet in different days by zones (periodic vehicle routing).

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Section 2 describes the problem of this case study, section 3 refers to the problem solving through two approaches, while section 4 presents the final results. Final considerations are given in Section 5.

2. PROBLEM DESCRIPTION – CASE STUDY

Data obtained from 3PL companies include data for March 2018 for nine regional centres located in Serbia. The total number of requests for delivery is 60,400 for the mentioned month. For this case study, three regional centres were observed that had the highest number of requests for delivery. The idea is that the delivery requirements are observed according to the capacity and number of pallets for each regional centre. In the current state of the company, the distribution of goods can be done every day - to every PTT object, six days a week. The PTT object is composed of several smaller objects which are located at near proximity. A heterogeneous fleet of vehicles was used. The conditions given in the observed case study are as follows: for small deliveries, one type of truck with a load of up to 4000 kg and 10 pallets is used, and these deliveries are routed. Direct deliveries are divided into large direct lines served by large capacity vehicles that can transport up to 23000 kg and 33 pallets, while small direct deliveries are realized by medium capacity vehicles that can transport up to 10000 kg and 20 pallets. Delivery data received from the company contains the required delivery dates, coordinates and quantities.

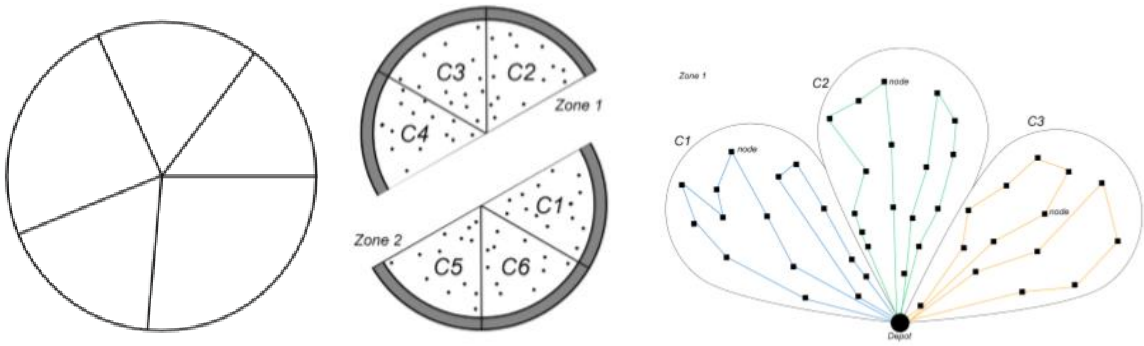

Figure 1. An example of distribution area zoning, Santana (2016)

3. SOLVING APPROACH

Solving approach is divided into four stages, which include: zoning, shifting of deliveries (between days), distribution of customer demands, and routing. Two approaches have been applied in solving routing problem, the first approach involves dividing into three zones (according to the number of pallets), while the second divides into two zones (according to number of PTTs). Moving deliveries between days according to zones is conducted in both approaches. The division of PTT deliveries for both approaches is the same: small shipments that are routed, large direct deliveries and small direct deliveries. Heuristic sweep algorithm was used for routing in the first, while in the second approach the excel tool VRP solver was used.

3.1. Two zone sweep algorithm approach

In this approach, the distribution centres were divided into two zones, where zone 1 is served on Monday, Wednesday and Friday, while zone 2 is operated on Tuesdays, Thursdays and Saturdays. Also, deliveries for PTT objects are consolidated according to assigned dates, where deliveries are always transferred to that specific zone for the day before.

For the routing of small deliveries, a heuristic sweep algorithm based on the application of polar coordinates was used, where the base is treated as a coordinate start (Santana, 2016). The coordinates used in the approach are given by the company as well as the real matrix of distances on the Serbian road network. The depot connects to the arbitrarily selected point and this point is called the first point. All other points connect to the base and then sort through the rising angles.

In this case, the TSP route is viewed as an approximation of the movement of the vehicle. The route begins with the first point, and then the remaining points join the route along the rising corners, taking care to respect the specified limits.

The second group of deliveries, or direct deliveries, are divided into those that are transported by large or medium capacity vehicles, all depending on the requested quantities. In case that the total delivery quantity, for a single PTT object, exceeds the number of pallets or the load capacity of the truck, more direct deliveries are formed.

3.2 Three zone VRP solver approach

The division of the zone was carried out according to the number of pallets, in three zones. Zone are balanced according to this parameter since it was assumed that the company uses its own fleet. After the division into zones, the shift of the delivery date was done in the following manner: all deliveries belonging to the zone 1 will be served on Monday and Thursday, those that belong to the zone 2 on Tuesdays and Fridays, and the deliveries that are in the zone 3 will be served on Wednesdays and Saturdays. Distribution of delivery depends on the initial conditions that are given.

VRP solver is used for routing, which provides solutions on the principle of the Large Neighborhood Search (LNS algorithm) used to solve the static problem. The necessary data entered in this tool are: number of depots, which is always one for each regional center; the number of objects to be serviced in one day, the average speed of the truck, the number of vehicle types (In this case one type of vehicle), whether it is necessary to return the vehicle to the depot. Other data that has to be filled are: locations, where is necessary to enter the names of the PTT objects, the coordinates, the service time of the facility, and the number of pallets that has to be delivered to each object. In the next sheet, the tool casts out all possible combinations of locations and it is necessary to enter the distances between each two PTT objects (data are given in the matrix of distance obtained from the company) and the time based on kilometres and the speed is calculated. In order to get the final solution, it is still necessary to enter the capacity data, the cash unit per kilometre, and the maximum number of vehicles a company can use for that day. The tool provides the ultimate solution where it shows total costs, how many vehicles have to be used, and the total kilometres travelled for each vehicle. On the basis of these data, the tool gives us a visual display of the route. For a more detailed view of how this tool works, as well as an overview of each step, take a look at Erdogan (2017).

4. COMPUTATIONAL RESULTS

Below are the results of zoning of one of the regional centres. Based on zoning, the service days were transferred, depending on the belonging to the zone. Figure 2 shows us a graphic representation of PTT objects for one regional centre. It is divided into two zones that are arranged according to polar coordinates. The first zone consists of the first 80 PTT objects, sorted by rising angles to half the number of objects, while the second zone has rest 79 PTT objects.

Figure 3 gives us a graphical representation of the space divided into three zones according to the number of pallets. On the basis of it, a clear difference is seen in the number of objects per zone, so zone 2 has the highest number of PTT objects, then zone 1 and at the end, zone 3 has the smallest number of PTT objects. The total number of pallets differs from the first approach, because all direct deliveries are excluded from observation before the zoning itself.

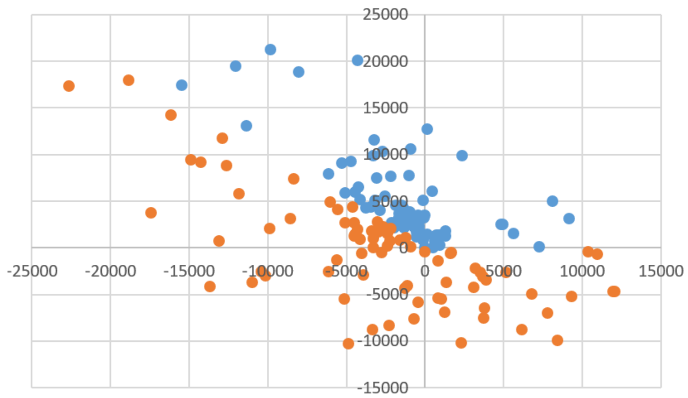

Figure 2. Graphic representation of PTT objects

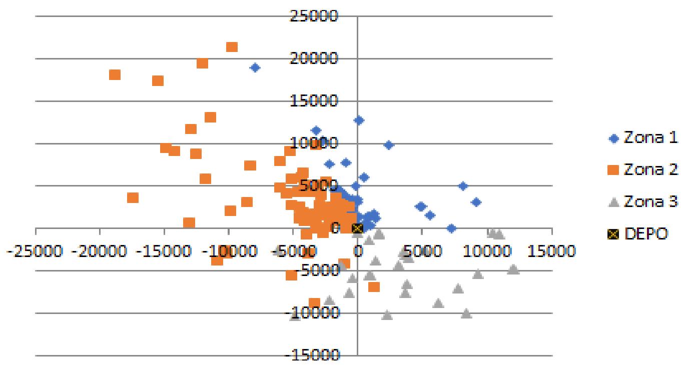

Figure 3. Graphical representation of three zones

Tables 1 is providing us with the ratio of the mass, the number of delivery pallets, and the number of PTT objects for one regional centre for two zoning approaches. By applying these two approaches we can see the balance by one criterion (in the first approach it is the number of PTT objects, while in the second it is the number of pallets) but also a disbalance according to other observed criteria.

Table 1. Overview of three basic parameters for zoning of one distribution region

	SWEEP ALGORITHM APPROACH		**VRP SOLVER APPROACH**		
	Zone 1	Zone 2	Zone 1	Zone 2	Zone 3
Kg	4161803.9	1615249.8	1208978.9	772552.7	1365426.5
Pallets	16665.9	4520.6	3258.0	3269.5	3258.6
Number of PTTs	80	79	45	74	29

Figure 4 shows us two visual views of one route (for two random days of the planning period). To the left is a large TSP route used to serve PTT objects classified in small deliveries on one day in March 2018. The route was obtained by a heuristic algorithm. On the right are several smaller routes, which are obtained using the VRP solver. Based on the entered data, the solver searches for a potential route solution to all locations, depending on the time and kilometre limit.

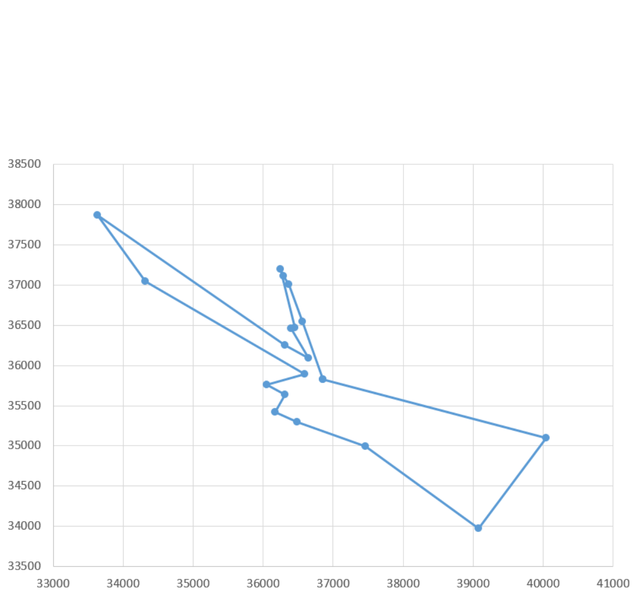

Figure 4. Example of vehicle routes obtained by two approaches

In Table 2, which presents the results of the first approach, can be seen that the cost reduction (given in monetary units) has decreased by 10% for all three observed regional centres. Significant savings occurred when small deliveries were realized, while large direct deliveries resulted in increased costs, which was expected.

Table 2. Results from the two zone sweep algorithm approach

		BEFORE ZONING				AFTER ZONING			
		100	104	105	Total	100	104	105	Total
LARGE DIRECT DELIV.	Km	17964.0	2683.7	18909.0	39556.7	19476.2	2683.7	18909.0	41068.9
	Cost	6826.3	1019.8	7185.4	15031.5	7401.0	1019.8	7185.4	15606.2
		Savings after zoning- direct deliveries by tractor units				*-8%*	*0%*	*0%*	*-4%*
MEDIUM DIRECT DELIV.	Km	22979.3	1630.5	14127.0	38736.8	23417.6	2075.2	16281.3	41774.1
	Cost	6572.1	466.3	4040.3	11078.7	6697.4	593.5	4656.5	11947.4
		Savings after zoning- direct deliveries by trucks				*-2%*	*-27%*	*-15%*	*-1%*
SMALL TRUCKS	Km	44970.0	28550.5	55057.8	128578.3	33182.8	21594.0	41804.7	96581.4
	Cost	10163.2	6452.4	12443.1	29058.7	7499.3	4880.2	9447.9	21827.4
		Savings after zoning- routing				*26.2%*	*24.4%*	*24.1%*	*24.9%*
TOTAL SAVINGS AFTER ZONING						**8%**	**18%**	**10%**	**10%**

Table 3 gives us individual and total costs, total kilometres, as well as savings for three regional centres using the second approach. Travel kilometres for routing has been reduced but they are increased for direct deliveries, while the overall savings for these three regional centres are significant and they are roughly equal to 25%.

Table 3. Results from the three zone VRP solver approach

		BEFORE ZONING				AFTER ZONING			
		100	104	105	Total	100	104	105	Total
LARGE DIRECT DELIV.	Km	9518.8	288.9	18908.9	28716.6	11632.7	477.6	20048	32158.3
	Cost	3617.1	109.7	7185.4	10912.2	4420.4	181.5	7618.516	12220.4
		Savings after zoning- direct deliveries by tractor units				*-18%*	*-24%*	*-6%*	*-12%*
MEDIUM DIRECT DELIV.	Km	39454.9	780.1	14126.9	54361.9	48096.6	971.2	14355.6	63423.4
	Cost	10284.1	223.1	4040.3	14547.5	13755.6	277.7	4105.7	18139.3
		Savings after zoning- direct deliveries by trucks				*-18%*	*-20%*	*-2%*	*-25%*
SMALL TRUCKS	Km	43458.4	16473.7	37285.1	97217.2	27354.9	11614.4	23236.6	62205.9
	Cost	9821.6	3717.1	8479.0	22017.7	6182.2	2624.8	5251.4	14058.4
		Savings after zoning- routing				*59%*	*42%*	*61%*	*26%*
TOTAL SAVINGS AFTER ZONING						**3%**	**24%**	**14%**	**24.9%**

5. CONCLUSION

By applying one of the approaches presented, the company could receive additional revenue in relation to the traditional approach they apply. Costs for direct deliveries have increased, due to the consolidation of deliveries in periodic replenishment strategy. The end result is a positive saving. From the attached results it can be noted that both approaches can generate significant savings, but they must be taken with reserve because a more detailed analysis, on a larger sample, is required, with a more complex structure of the vehicle fleet. As it is mentioned in Chapter 4, by applying these two approaches, there has been a balance of one of the three observed criteria, but also disbalance on other**s.** Also, it is necessary to consider the current behaviour of 3PL provider's clients who have the freedom to schedule delivery every day for all PTT objects, i.e it is necessary to attract clients to a new business model with periodic delivery to objects, where potential savings would be fairly distributed to both clients and 3PL provider.

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