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Transport Logistics
Preliminary Communication
Accepted: Aug. 1, 2013
Approved: Apr. 8, 2014

RANKING OF LOGISTICS SYSTEM SCENARIOS FOR CENTRAL BUSINESS DISTRICT

ABSTRACT

This paper presents the procedure for logistics system scenario selection for the central business district (CBD) of the city in the phase of significant urban changes. Scenarios are defined in accordance with the overall logistics concept of the city. Conflicting goals of stakeholders (residents, shippers and receivers, logistics providers and city government) generate a vast number of criteria that need to be included when selecting the scenario for the city area logistics system. Due to limited resources and linguistic assessment of criteria, fuzzy extensions of conventional multi-criteria decision-making (MCDM) methods were used. Fuzzy "analytical hierarchy process" (FAHP) is applied to determine the relative weights of evaluation criteria, and fuzzy "technique for order preference by similarity to ideal solution" (FTOPSIS) is applied to rank the logistics systems scenarios. This paper contributes to the literature in the field of city logistics (CL), as it applies the integrated FAHP-FTOPSIS method for the evaluation of scenarios, which are also integrated combinations of different CL initiatives. The integrated combined approach proved to be accurate, effective and a systematic tool for the decision support in the process of selecting CBD logistics scenarios.

KEY WORDS

city logistics; central business district; logistics system scenario; MCDM

1. INTRODUCTION

With the growing demands for more efficient supply and environmental protection, the interest in city logistics, i.e. goods distribution, and logistics systems of urban areas is increasing. In order to obtain relevant information and overview of the city logistics systems state, major European and national research projects were implemented. They all suggest that the state of urban logistics is critical. In order to make the logistics activities less a routine and thereby more efficient, many initiatives were undertaken, especially in terms of impacts on the environment and quality of service. However, changes are slow and it seems that none of the city logistics participants want to make faster progress [1]. The main problem is the lack of planning activities, comprehensive and long-term policy of city logistics. Urban planners' decisions are often inadequate, without the necessary research, analysis and insight into different measures and impacts.

Attractive central city areas of large cities (Central Business District, CBD) partially or completely change their purpose while developing. This paper gives an overview of the planned urban changes of the part of the central area of Belgrade, which has access to the Danube River (Central Business Danube District, CBDD). The development of various business and commercial facilities with modern objects, in the architectural sense, has been planned for this location. The new plan requires new logistics solutions, which in such cases are defined in several scenarios. Each logistics scenario has its own value in terms of various criteria of CBD efficient functioning. Since this issue attracts the attention of all city structures and functions, the process of decision-making about the future logistics scenario is derived from various, mostly conflicting objectives and criteria, and with the application of the integrated FAHP-FTOPSIS method.

2. DEFINING THE PROBLEM

Forms and physical components of procurement, storage, and distribution of goods have changed with the evolution of the urban environment. In the initial stages of development, ports, harbours, and squares represented the commodity gates of urban areas. With spatial expansion of cities, development of transport infrastructure and rising prices of urban land, stopping places for macro-distribution flows are moving to peripheral areas. Growth of road transport, expansion of warehouses and logistics centre networks, as well as increased requirements in terms of quality and diversity of logistics services have resulted in a significant increase in the number of commercial vehicles and worrying loss of viability of some cities. In many countries, state and local governments have tried to implement some concepts of city logistics, but with varying success. From the planning perspective, the city authorities mainly deal with the current situation and short-term solutions to the problems.

Planning and control of logistics activities is reduced to the application of city regulations that define the time of delivery, size or capacity of delivery vehicles. There are only a few cities where logistics is seen as a service which needs help to be organized more efficiently. In most cities, the existing legislation and policies of urban freight transport and logistics cannot fully respond to the significant changes that have taken place in the use of the land, the sectors of production, distribution and consumption. Space for logistics activities (freight terminals, city harbours, warehouses) disappears from the cities. Expensive urban land changes the purpose, new commercial and housing facilities that generate significant flows of goods and require the concept of modern logistics are developing.

Belgrade is, like many cities on the riverside, mainly developed and spread radial-concentrically with regard to the traditional centre and river port. In the initial stages of development, many trade and distribution as well as industrial firms favourably inhabited the port and its surroundings and developed their own warehousing and distribution activities. In the current situation, the activities that are carried out in this area have significant adverse impacts on the surroundings from economic, environmental and social aspects. The major problem is the volume of flows that transit CBDD. About 80% of commodity flows carried out through the existing CBDD logistics systems are not intended for supplying the CBD. These flows initiate the daily start of thousands of road freight vehicles.

The observed urban area, CBDD, becomes an increasingly attractive location for more profitable business and commercial facilities and therefore, the restructuring of existing urban areas is required. Very valuable land equipped with old technology for storage and handling systems, runs a large number of vehicles and in many cases performs the logistics function for users who are not in the immediate area of the city of Belgrade. In addition to the outdated concept of structuring, inadequate utilization of space, and outdated technology, this area also lacks logistics scenarios that would be consistent with the city development concepts. The basic idea is to free the observed space of unnecessary logistical structures, to maintain and modernize the system of logistics for the CBD and coordinate it with the concept of a combined centralized-decentralized logistics system of the city [2]. Analysis of logistics scenario of the CBD and selection of the best solution for a broad set of interests is a central issue and task, and this is discussed through the case study in this paper.

3. CBDD LOGISTICS SYSTEMS SCENARIOS

The key elements for defining future logistics concept for CBDD are as follows: causes for settlement of the observed area; the possibility of displacement, dislocation; the necessity of certain systems' existence at the location; the place and role of CBDD's logistics system in the logistics of the city; and compatibility of logistics facilities with new development plans of CBDD.

The existing urban plans of the observed area are under the pressure of requirements for the new revision of the land use. Changes of the port system ownership and different business visions had a significant impact on the setting of the three scenarios of the CBDD logistics system [3]:

S1: The scenario of minimal infrastructural changes. This refers to the introduction of new technologies into existing logistics systems while maintaining the function of the port and railway freight station.

S2: The scenario of significant changes. This refers to the displacement of part of the logistics and their related systems from the region, modernization of intermodal terminal, City Logistics Terminal (CLT) development and application of eco-vehicles.

S3: The scenario of complete changes. This refers to the dislocation of the port and railway freight station, development of CLT with minimal configuration, and application of cargo trams and eco-vehicles.

Scenario S1 involves the retention and modernization of the existing structures and subsystems in the observed area (*Figure 1*). The port, which would remain in CBDD, would retain certain functions, primarily the intermodal transport function. In this case, one should expect further development and modernization of intermodal terminals. The existing storage and distribution systems could increase their efficiency with the use of new technologies (advanced machinery, automation, telematics systems, etc.). In this scenario it is possible to expect the development of new, modern logistics systems, which would be acceptable solutions for the observed area in terms of architecture and civil engineering. In the functional sense, new logistics systems would be the answer to the growing need for VAL services (Value Added Logistics), deliveries to specific assumption zones (pickup points), professional warehousing services, reverse logistics services, etc.

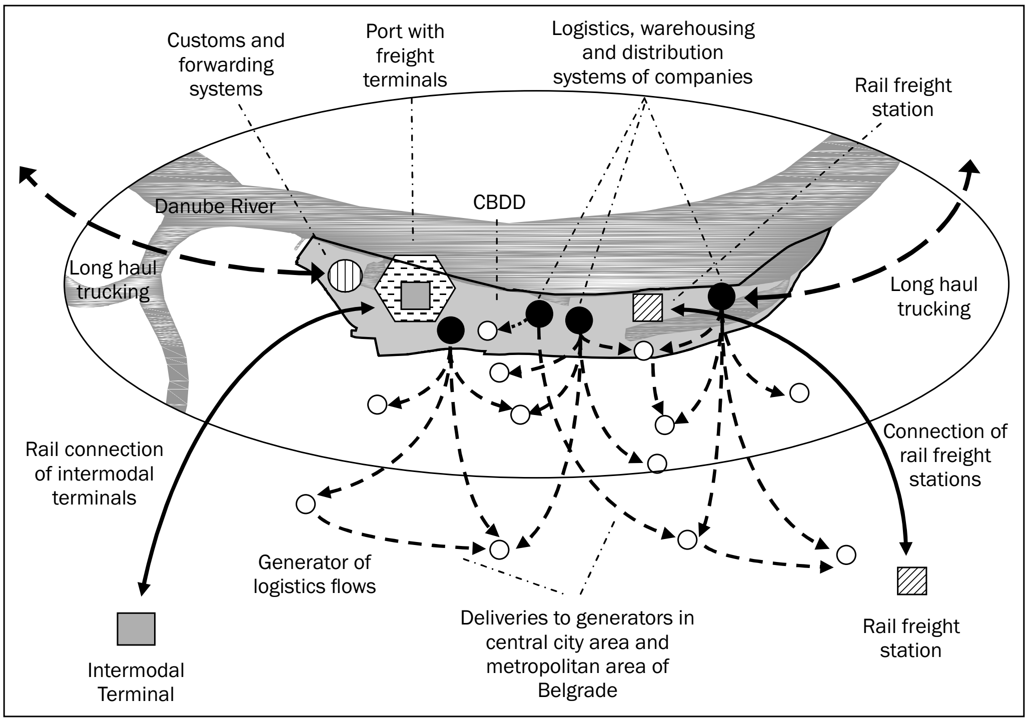

Figure 1 - Logistics system of CBDD according to scenario S1

Scenario S2 is based on the reduction of distribution and storage systems, the presence of which is not necessary in CBDD, as well as shipping, customs, and other related activities that are not necessary for the supply of CBD. This scenario implies the modernization of the intermodal terminal as the trimodal node and the development of a CLT for consolidated deliveries to generators in the catchment area (*Figure 2*). These two sub-systems have the ability for railway connection with intermodal terminals in other locations, such as freight villages (FVs) on the edge of the city, using the system of shuttle trains. This would lead to significant reduction of railway facilities, but it would enhance the role of railway in effective connection of this area. CLT would supply the CBD with a variant of small commercial eco-vehicles. The measure of using alternative, eco-friendly vehicles in order to reduce negative impacts on the environment is a growing trend, and almost always combined with CLT.

Scenario S3 implies dislocation of all existing port complex facilities and railway freight station(s), and the entire observed area of CBDD remains a business

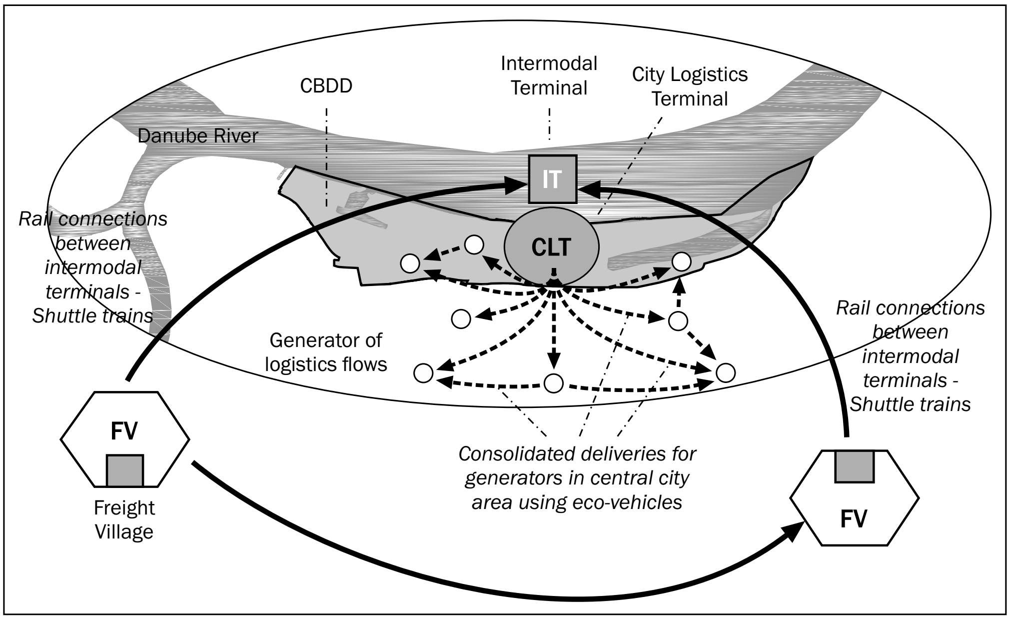

Figure 2 - Logistics system of CBDD according to scenario S2

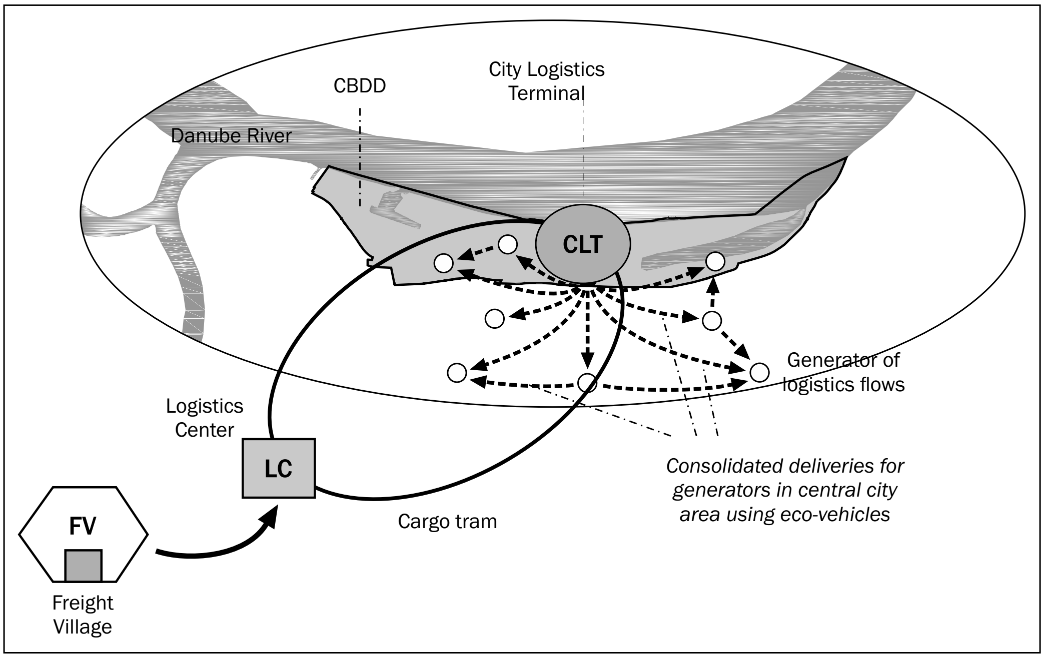

Figure 3 - Logistics system of CBDD according to scenario S3

and shopping centre with associated restaurants, cultural and sports facilities. This scenario would be in accordance with the "logistics sprawl" [4] which has become a worldwide phenomenon, and implies that logistics is increasingly taken away from the heart of the city. However, commercial contents that would settle the area of CBDD, together with the existing commercial contents in central city areas cannot operate without logistics. Attractiveness and functionality of the system require accompanying logistics system with a minimum and efficient configuration, which in the physical and traffic terms, can be done by introducing CLT. The goods would be delivered to the terminal from the logistics centre in another location in the city, using the cargo tram. Goods distribution from the CLT to the generators in the central city area, as well as the CBDD would be performed with electric vehicles (*Figure 3*).

4. CRITERIA FOR ASSESSING LOGISTICS SYSTEM SCENARIOS

The described scenarios of logistics system in CBDD can be distinguished in terms of the number of criteria. The criteria used for their evaluation in this paper are described below.

C1. *The degree of congestion caused by heavy freight vehicles at the access points and on the roads in CBDD*. According to scenario S1, the number of road freight vehicles would be maintained and possibly increased, which would lead to even more traffic congestion. With the dislocation of the systems which, in technological and spatial sense, are not related to the port and intermodal transport and with the consolidated distribution of goods in scenarios S2 and S3, the number of freight vehicles would be significantly reduced, and thus the degree of traffic congestion would be reduced with it.

C2. *The degree of space occupancy by the logistics systems that are not needed in the CBDD (necessity of existence)*. According to scenario S1, a certain number of CBDD logistics system users make deliveries to recipients outside of Belgrade from this site. By dislocating these activities and concentrating only on supplying the CBD, the occupied areas can be significantly reduced in scenario S2, and especially in scenario S3.

C3. *Investment for the development of systems*. Development of CBDD logistics systems in scenario S1 requires the least investment because of the fewest changes from the current situation. Investments for systems development according to scenarios S2 and S3 are significant and depend on the micro-location, size and structure of the planned facilities.

C4. *Costs of goods delivery*. According to previous studies, the delivery costs are reduced by using CLT and concept of flows consolidation for multiple users. The concept(s) proposed in scenarios S2 and S3 have effects in terms of logistics costs for any company that deals with the distribution of goods in urban areas.

C5. *Time losses in inbound-outbound transport*. In the current situation, after completion of the operations of loading, unloading, customs clearance, etc., vehicles remain in the port complex for several hours thereby avoiding crowds on the city street network. These losses could be substantial in scenario S1, but they are significantly reduced in scenarios S2 and S3.

C6. *The quality of logistics service*. By using modern storage systems and systems for tracking and vehicle navigation during delivery, logistics service quality parameters could be significantly improved. Accordingly, scenarios S2 and S3 are better solutions for all users who may be supplied from CBDD in the future.

C7. *Ecological and energy aspects*. By eliminating long haul, especially transit flows, and by applying the concept of consolidation and environmentally acceptable systems, as well as technologies of freight transport, the total number of road freight vehicles, and thus the negative environmental impacts and energy consumption in scenarios S2 and S3 could be significantly reduced compared to the current state.

C8. *Security aspect*. Reduction of the amount of traffic and congestion on city roads reduces the number of conflicting situations. According to this parameter, it is evidently an advantage of scenarios S2 and S3.

C9. *Logistics chains complexity*. Every stopping of the goods flow and its transformation inside terminals, logistics centres, increases the logistics chains complexity, especially in the final stage of goods distribution. The application of scenario S3 requires the highest degree of cooperation and consolidation, i.e. it represents the most complex realization of logistics chains.

C10. *Technological and visual integration of logistics systems in urban environment*. A difference in relation to logistics systems in scenario S1 can be created by constructing commercial facilities with modern architectural solutions. On the other hand, modern systems of goods distribution by using electric vehicles and cargo trams are embedded into the modern architectural structure. The CLT can also be derived as a modern facility with which, in scenarios S2 and S3, the logistics solutions and environment can be technologically and visually aligned and brought together.

5. RANKING LOGISTICS SYSTEM SCENARIOS USING THE INTEGRATED FAHP-FTOPSIS METHOD

The application of the fuzzy set theory [5] enables decision makers to include immeasurable, incomplete, inaccessible and partially unknown information into an MCDM model. In literature, there are various examples of applications of fuzzy extension of conventional MCDM methods on different logistics and transport problems: global logistics strategies identification [6], solid waste transhipment site selection [7], bus timetabling [8], etc. In this paper, for selecting the logistics system scenario for the part of the central city area, an integrated FAHP-FTOPSIS method is used. The FAHP method is applied to determine the relative weights of the evaluation criteria, and FTOPSIS is used for gaining the final rank of the logistics system scenarios. The applied methods are described with more details below.

5.1 Determining the weights of criteria using Fuzzy AHP method

Although conventional AHP [9], besides the quantitative one, also takes into account the quality criteria, it cannot depict the ambiguity and vagueness of the decision makers' thinking. Therefore, to solve the hierarchical fuzzy problems, a fuzzy AHP method is developed as a fuzzy extension of the AHP method [10]. The process of applying FAHP begins with forming a matrix for pair-wise comparison of criteria. A linguistic scale shown in *Table 1*, which can be converted into triangular fuzzy numbers, is used for the comparison of criteria. For assessing the importance of one criterion against another, the linguistic expressions are used and thus form the matrix for the comparison of criteria.

Table 1 - Fuzzy scale for the weights of criteria

Linguistic expression	Membership function
Absolutely preferable (AP)	(8, 9, 10)
Strongly preferable (SP)	(6, 7, 8)
Quite preferable (QP)	(4, 5, 6)
Moderately preferable (MP)	(2, 3, 4)
Equally important (EI)	(1, 1, 2)

There are several approaches to obtain the final values of criteria from the pair-wise comparison matrices. In this paper a logarithmic fuzzy preference programming (LFPP) method is used, which was developed by Wang and Chin [11] by extending the method of fuzzy preference programming (FPP), developed by Mikhailov [12].

The FPP method starts with forming a fuzzy comparison matrix ($\tilde{A}$), the elements of which are triangular fuzzy judgments $\tilde{a}_{jk} = (l_{jk}, m_{jk}, u_{jk})$ of comparing element j in relation to element k. Wang and Chin, in the LFPP method, take logarithm values of fuzzy judgment $\tilde{a}_{jk}$ from matrix $\tilde{A}$ by the following approximate equation:

$$\ln \tilde{a}_{jk} \approx (\ln l_{jk}, \ln m_{jk}, \ln u_{jk}),\; j,k = 1,2,\ldots,n \qquad (1)$$

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

$$\mu_{jk}\left(\ln\left(\frac{w_j}{w_k}\right)\right)=\begin{cases}\dfrac{\ln(w_j/w_k)-\ln l_{jk}}{\ln m_{jk}-\ln l_{jk}}, & \ln\left(\frac{w_j}{w_k}\right)\le \ln m_{jk}\\ \dfrac{\ln u_{jk}-\ln(w_j/w_k)}{\ln u_{jk}-\ln m_{jk}}, & \ln\left(\frac{w_j}{w_k}\right)\ge \ln m_{jk}\end{cases} \quad (2)$$

where $\mu_{jk}(\ln(w_j/w_k))$ is the membership degree of $\ln(w_j/w_k)$ belonging to the approximate triangular fuzzy judgment $\ln\tilde{a}_{jk}=(\ln l_{jk},\ln m_{jk},\ln u_{jk})$, and w_j are crisp values of the priority vector $W=(w_1,\ldots,w_n)^T>0$,

$$\sum_{j=1}^{n} w_j = 1.$$

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

$\lambda=\min\{\mu_{jk}(\ln(w_j/w_k))\,|\, j=1,\ldots,n-1; k=j+1,\ldots,n\}$.

The resultant model can be constructed as:

$$\max\lambda \quad s.t.\begin{cases}\mu_{jk}(\ln(w_j/w_k))\ge\lambda, j=1,\ldots,n-1; k=j+1,\ldots,n,\\ w_j\ge 0, j=1,\ldots,n,\end{cases} \quad (3)$$

or

$$\max 1-\lambda \quad s.t.\begin{cases}\ln w_j-\ln w_k-\lambda\ln(m_{jk}/l_{jk})\ge\ln l_{jk},\\ \quad j=1,\ldots,n-1; k=j+1,\ldots,n,\\ -\ln w_j+\ln w_k-\lambda\ln(u_{jk}/m_{jk})\ge-\ln u_{jk},\\ \quad j=1,\ldots,n-1; k=j+1,\ldots,n,\\ w_j\ge 0, j=1,\ldots,n\end{cases} \quad (4)$$

To avoid membership degree λ from taking a negative value, the nonnegative deviation variables δ_{jk} and η_{jk} for $j=1,\ldots,n-1$ and $k=1,\ldots,n$ are introduced such that they meet the following inequalities:

$$\ln w_j-\ln w_k-\lambda\ln(m_{jk}/l_{jk})+\delta_{jk}\ge\ln l_{jk},\quad j=1,\ldots,n-1; k=j+1,\ldots,n$$

$$-\ln w_j+\ln w_k-\lambda\ln(\mu_{jk}/m_{jk})+\eta_{jk}\ge-\ln u_{jk},\quad j=1,\ldots,n-1; k=j+1,\ldots,n$$

It is most desirable that the values of the deviation variables be as small as possible. Accordingly, the following LFPP-based nonlinear priority model for fuzzy AHP weight derivation is proposed:

$$\min J=(1-\lambda)^2+M\cdot\sum_{j=1}^{n-1}\sum_{k=j+1}^{n}(\delta_{jk}^2+\eta_{jk}^2)$$

$$s.t.\begin{cases}x_j-x_k-\lambda\ln(m_{jk}/l_{jk})+\delta_{jk}\ge\ln l_{jk},\\ \quad j=1,\ldots,n-1; k=j+1,\ldots n,\\ -x_j+x_k-\lambda\ln(u_{jk}/m_{jk})+\eta_{jk}\ge-\ln u_{jk},\\ \quad j=1,\ldots,n-1; k=j+1,\ldots n,\\ \lambda, x_j\ge 0, j=1,\ldots,n,\\ \delta_{jk},\eta_{jk}\ge 0, j=1,\ldots,n-1; k=j+1,\ldots,n,\end{cases} \quad (5)$$

where $x_j=\ln w_j$ for $j=1,\ldots,n$, and M is a specified, sufficiently large constant such as $M=10^3$.

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

$$w_j^*=\frac{\exp(x_j^*)}{\sum_{k=1}^{n}\exp(x_k^*)},\ j=1,\ldots,n \quad (6)$$

where exp() is the exponential function, namely $\exp(x_j^*)=e^{x_j^*}$ for $j=1,\ldots,n$.

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

5.2 Scenario selection using Fuzzy TOPSIS method

Despite its popularity and simplicity of use, the TOPSIS method [13] is often criticized for its inability to adequately handle uncertain and imprecise perception of the decision makers. Fuzzy extension of the TOPSIS method [14] is performed by introducing triangular fuzzy numbers for evaluating the alterna-

Table 2 - Comparison of criteria and final values of criteria weights

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	w_j
C_1	/	-	-	-	EI	-	MP	QP	MP	QP	0.074
C_2	MP	/	-	EI	MP	EI	QP	SP	QP	SP	0.148
C_3	QP	MP	/	MP	QP	MP	SP	AP	SP	AP	0.296
C_4	MP	-	-	/	MP	EI	QP	SP	QP	SP	0.148
C_5	-	-	-	-	/	-	MP	QP	MP	QP	0.074
C_6	MP	-	-	-	MP	/	QP	SP	QP	SP	0.148
C_7	-	-	-	-	-	-	/	MP	EI	MP	0.037
C_8	-	-	-	-	-	-	-	/	-	EI	0.019
C_9	-	-	-	-	-	-	-	MP	/	MP	0.037
C_{10}	-	-	-	-	-	-	-	-	-	/	0.019

tives (scenarios). To evaluate scenarios in relation to criteria, linguistic assessments are used, which can be converted into fuzzy numbers (*Table 3*).

Table 3 - Fuzzy scale for the values of the scenarios

Linguistic expression	Membership function
Very poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

The triangular fuzzy numbers $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ which represent the value of scenario i in relation to the criterion j form a fuzzy decision matrix. In order to transform various scenario evaluation scales into a comparable scale, it is necessary to perform normalization. The normalization formula for the classical TOPSIS method is complicated, and therefore the linear scale transformation is used here. With this method the different ranges of triangular fuzzy numbers are reduced in the interval [0, 1] as follows [14]:

$$\tilde{r} = \left(\frac{\tilde{a}_{ij}}{c_j^*}, \frac{\tilde{b}_{ij}}{c_j^*}, \frac{\tilde{c}_{ij}}{c_j^*}\right),\ j \in B;\ c_j^* = \max_i c_{ij}\ \text{if}\ j \in B \qquad (7)$$

$$\tilde{r} = \left(\frac{a_j^-}{c_{ij}}, \frac{b_j^-}{b_{ij}}, \frac{c_j^-}{a_{ij}}\right),\ j \in C;\ a_j^- = \min_i a_{ij}\ \text{if}\ j \in C \qquad (8)$$

where *B* and *C* are sets of benefit and cost criteria, respectively.

In this way normalized fuzzy decision matrix is formed, which can be written as:
$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}$ where $i = 1,2,\ldots,m$; and $j = 1,2,\ldots,n$, are indices of scenarios and criteria, respectively.

Taking into account various importance of the criteria, a weighted normalized fuzzy decision matrix can be formed:

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n},\ i = 1,2,\ldots,m;\ j = 1,2,\ldots,n$$

where

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes w_j \qquad (9)$$

and w_j denotes the weights of criteria *j*.

Based on the weighted normalized fuzzy decision matrix, fuzzy positive ideal solution of scenario (FPIS, S*) and fuzzy negative ideal solution of scenario (FNIS, S-), are defined as [15]:

$$S^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*),\ \tilde{v}_j^* = \max_i v_{ij},\quad i = 1,2,\ldots,m\ \ j = 1,2,\ldots,n$$

$$S^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-),\ \tilde{v}_j^- = \min_i v_{ij},\quad i = 1,2,\ldots,m\ \ j = 1,2,\ldots,n$$

The distance of each scenario from S* and S- can be calculated as:

$$\tilde{d}_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*),\ i = 1,2,\ldots,m \qquad (10)$$

$$\tilde{d}_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-),\ i = 1,2,\ldots,m \qquad (11)$$

where $\tilde{d}$ represents the distance between two fuzzy numbers which can be calculated in different ways. In this paper it is calculated using the following formula [16]:

$$\begin{aligned}\tilde{d}(\tilde{\rho}, \tilde{\tau}) = \\ &= (\rho_2 - \tau_2)^2 + (1/2)(\rho_2 - \tau_2)[(\rho_3 + \rho_1) - (\tau_3 + \tau_1)] + \\ &+ (1/9)[(\rho_3 - \rho_2)^2 + (\rho_2 - \rho_1)^2 + (\tau_3 - \tau_2)^2 + (\tau_2 - \tau_1)^2] - \\ &- (1/9)[(\rho_2 - \rho_1)(\rho_3 - \rho_2) + (\tau_2 - \tau_1)(\tau_3 - \tau_2)] + \\ &+ (1/6)(2\rho_2 - \rho_1 - \rho_3)(2\tau_2 - \tau_1 - \tau_3) \qquad (12)\end{aligned}$$

where $\tilde{\rho} = (\rho_1, \rho_2, \rho_3)$ and $\tilde{\tau} = (\tau_1, \tau_2, \tau_3)$ are two triangular fuzzy numbers. Once the values $\tilde{d}_i^*$ and d_i^- for each scenario $S_i\ (i = 1,2,\ldots,m)$ are obtained, the closeness coefficient (CC) can be defined as follows [17]:

$$CC_i = \frac{\tilde{d}_i^{-2}}{\tilde{d}_i^{*2} + \tilde{d}_i^{-2}},\ i = 1,2,\ldots,m. \qquad (13)$$

It is obvious that scenario S_i is closer to $(FPIS, S^*)$ and further from $(FNIS, S^-)$ as CC_i is approaching 1. Accordingly, on the basis of closeness coefficient to ideal solution, the order of scenarios may be determined and then the best one from the feasible set selected.

For the final selection of the CBDD logistics system scenario and the application of the FTOPSIS method, *Table 4* presents the judgments of scenarios for the selected criteria with linguistic expressions defined in *Table 3*.

Table 4 - Evaluation of scenarios with respect to criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
S_1	P	VP	G	MP	P	P	VP	VP	MG	F
S_2	MG	G	MG	MG	MG	G	MG	MG	F	G
S_3	VG	VG	MP	G	G	VG	G	G	MP	VG

Linguistic terms were converted into fuzzy numbers, and using equation (7) fuzzy values were normalized since all the criteria were seen and treated as benefit criteria. Multiplying by the obtained final weights of criteria, normalized weighted fuzzy values are obtained, i.e. weighted fuzzy decision matrix is formed. A fuzzy positive ideal solution $(FPIS, S^*)$ and fuzzy negative ideal solution $(FNIS, S^-)$ are defined. Distances of all scenarios from positive and negative ideal solutions are calculated using the equations (10) and (11), and afterwards, the values of closeness coefficients (CC_i) for all scenarios are calculated using equation (13). These values and the final ranking of scenarios are shown in *Table 5*.

Table 5 - Final ranking of scenarios

Scenario	d_i^*	d_i^-	CC_i	Rank
S_1	0.113	0.062	0.235	3
S_2	0.014	0.106	0.984	1
S_3	0.067	0.109	0.726	2

The solution of this MCDM problem is scenario S2, i.e. logistics system with intermodal terminal and CLT and with the displacement of a large number of existing logistics subsystems, which is unnecessary for CBDD.

6. DISCUSSION

Scenario S1 includes the least changes in relation to the existing system, least investments and least complexity in logistics chains realization. Despite that, this scenario is significantly worse than scenarios S2 and S3. Traffic congestion by heavy freight vehicles, costs of goods delivery, ecological, security and energy impacts, as well as the quality of logistics services affected the ranking of scenario S1.

Scenarios that involve significant (S2) or complete (S3) changes of the CBDD logistics system have significantly higher values. The common characteristics of scenarios S2 and S3 are cooperation and consolidation. The application of the concept of consolidated goods delivery over CLT causes many positive effects, such as reducing the number of vehicles, reducing the number of vehicle kilometres, improved vehicle efficiency, reduced fuel consumption, reduction of external costs, etc. In addition, this concept justifies the use of new technologies for warehousing and goods distribution, which significantly improves the quality parameters of logistics services. The key advantage of scenario S2, compared to scenario S3, is less investment in the system development. On the other hand, this scenario is also more acceptable for system users because it requires a lesser degree of commodity flows transformation.

From the standpoint of the environment and quality of logistics services, scenario S3 with CLT, cargo tram and electric vehicles is the most acceptable one. Since this scenario involves additional investment and complete dislocation of the port system, it could constitute the next development phase of the logistics of the central city area.

Three scenarios, a number of stakeholders, and the ten criteria are setting a complex task for the decision makers. At least one scenario suits each stakeholder. The best solution to this task is the application of the MCDM method, i.e. the approach that provides visible selectivity. This requirement is achieved by using a specially defined set of criteria and the proposed method. Since the weights of criteria and values of alternatives are vague and imprecise, fuzzy extensions of AHP and TOPSIS methods are applied to solve the problem of logistics system scenario selection. The advantage of AHP method is its relative effectiveness in solving problems with a large number of criteria and mutual comparison of all pairs (of criteria, alternatives). However, the application of the AHP method is not recommended for solving the problems with a large number of criteria and alternatives because it leads to the formation of too many pair-wise comparison matrices. On the other hand, the logic of the TOPSIS method is rational and understandable. The method permits the pursuit of the best alternatives for each criterion which can be expressed in a simple mathematical form. The computation process is simple, and the solution is obtained in a shorter period of time.

7. CONCLUSION

The CBD of the city, as an area which generates complex goods flows, is often subject of research. Accordingly, the Danube part of Belgrade CBD, CBDD, is analyzed in this paper, with the goal of processes rationalization and creation of the efficient logistics system.

The current situation in Belgrade, in terms of logistics, is not in accordance with the optimal centralized-decentralized concept of freight villages and city logistics terminals. Logistics of the city is without necessary degree of concentration and consolidation of flows and logistics service providers. Change of use of part of the CBD and plan for the development of various business and commercial contents requires the definition of logistics scenarios that would meet the new requirements, but also solve the existing problems of the city logistics.

Three logistics systems scenarios are presented in this paper, where scenario S1 involves minimal changes, restructuring and partial modernization of existing contents, and scenarios S2 and S3 represent modern city logistics solutions. Each of the defined scenarios is a complex logistics system, and it is necessary to analyze all aspects of its implementation in order to accomplish the final selection of scenarios. This is possible to perform by applying a vast number of criteria which should include more measurable and immeasurable factors that influence the assessment of scenarios, and provide a holistic approach to problem solving. In this paper, ten criteria are defined for scenario evaluation, and for their ranking, the MCDM method which combines FAHP and FTOPSIS is used. In relation to defined criteria, scenario S2 is chosen as the most suitable for solving logistics problems for the central city area.

MCDM methods give support to decision makers (planners, city administration, logistics service providers, users, etc.) when selecting logistics scenarios for the CBD of bigger urban areas, which was in this paper successfully performed for Belgrade. The integrated FAHP-FTOPSIS method is applied for the first time to solve the problem of selecting the CBD logistics scenario, which is a combination of various initiatives of city logistics and should satisfy the objectives of all stakeholders. The proposed integrated approach systematically selects the best scenario despite the conflicting objectives, unclear and imprecise weights of criteria, and values of the alternatives. Accordingly, the contribution of this paper is to propose an efficient and effective framework for decision-making in solving the problem of the selection of urban area logistics scenario. Selection and structuring of the criteria for scenario evaluation is a special research field. Criterion of necessity of existence, introduced for the evaluation of urban area logistics scenarios, is not easy to quantify as it must be viewed from various aspects (spatial, economic, environmental, and social). The impact of this criterion on decision makers can be the subject of future research.

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REZIME

RANGIRANJE SCENARIJA LOGISTIČKOG SISTEMA CENTRALNE POSLOVNE ZONE

U radu je prikazan postupak izbora scenarija logističkog sistema centralnog poslovnog prostora (central business district, CBD) grada u fazi značajnih urbanističkih promena. Scenariji su definisani u skladu sa celokupnim konceptom logistike grada. Konfliktni ciljevi interesnih grupa (stanovnici, pošiljaoci i primaoci, logistički provajderi i gradska uprava), generišu veliki broj kriterijuma koje je neophodno uključiti u proces izbora scenaria logističkog sistema gradske zone. Zbog ograničenih resursa i lingvističke ocene kriterijuma, za izbor scenarija korišćena su fazi proširenja konvencionalnih metoda višekriterijumskog odlučivanja (VKO). Relativne težine kriterijuma dobijene su primenom metode fuzzy "analytical hierarchy process" (FAHP), a za rangiranje scenarija logističkog sistema primenjena je metoda fuzzy "technique for order preference by similarity to ideal solution" (FTOPSIS). Ovaj rad daje doprinos literaturi iz oblasti city logistike (CL), s obzirom da primenjuje integrisanu FAHP-FTOPSIS metodu za izbor scenarija, koji su takođe integrisana kombinacija različitih inicijativa CL. Integrisan kombinatorni pristup pokazao se kao precizan, efektivan i sistematičan alat za podršku odlučivanju prilikom izbora scenarija logističkog sistema CBDa.

KLJUČNE REČI

city logistika, central business district, scenario logističkog sistema, VKO

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