CITY LOGISTICS CONCEPTS OF BELGRADE

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

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

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1. INTRODUCTION

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

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

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

2. DEFINING THE PROBLEM

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

The biggest logistical problems are present in the central city area. This area occupies about 11% of the city, it is home to 40% of the population and it contains almost 60% of the jobs. The area is characterized by a large number of small and frequent deliveries because 50% of the generators are small stores of trade, service and catering activities [3]. The port and rail intermodal terminal, which are serving the long haul flows and generate the entry of heavy freight vehicles, are situated in this area. On the other hand, many firms developed warehousing and distribution activities on the high-valuable land of the central area. The existing logistics systems initiate movement of a large number of freight vehicles and in many cases perform the function of logistics for users who are not situated in the city area.

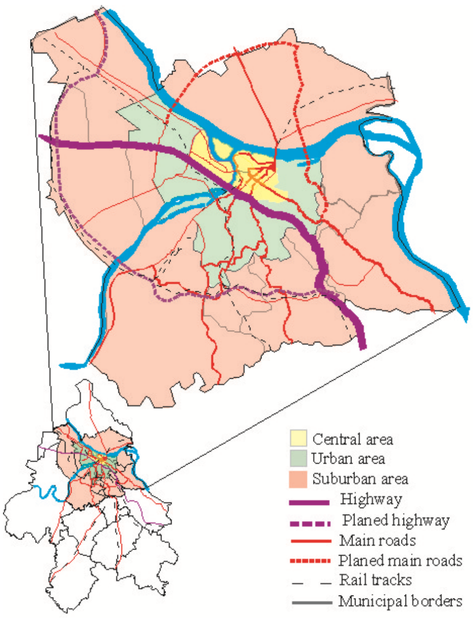

Figure 1. Areas and major traffic routes of Belgrade

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

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

3. CITY LOGISTICS CONCEPTS

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

CL1: Decentralized, satellite system with the dominant role of road transport.

CL2: Centralized-decentralized system with the application of cargo trams.

CL3: The network core with the application of cargo trams and electric vehicles.

CL4: The network system with intermodal transport.

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

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

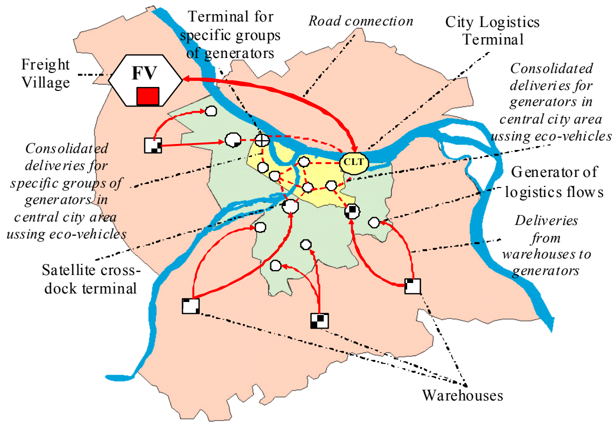

Figure 2. The CL1 concept

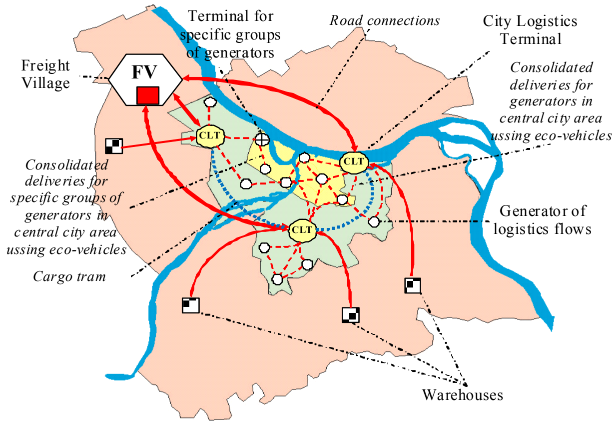

Figure 3. The CL2 concept

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

The CL4 concept is focused on the development and implementation of intermodal transport in the function of city logistics. It involves the formation of a network of logistics centers of different categories and more significant participation of railways in the realization of flows. At the site of Ada Huja, a CLT for consolidated delivery for the generators in the gravity area, as well as intermodal transport terminal, would be developed. These two systems would have the possibility for rail connection with intermodal terminals in other locations, i.e. FVs on the outskirt of the city, with the use of shuttle trains. Part of the railway infrastructure passing through the central city area, would be retained, but with the aim of increasing the role of railways in connecting urban areas. From the site of Ada Huja, flows between CLTs would be realized through a circular cargo tram line. Distribution of goods within the CLT zone would be realized with the application of small delivery eco-vehicles.

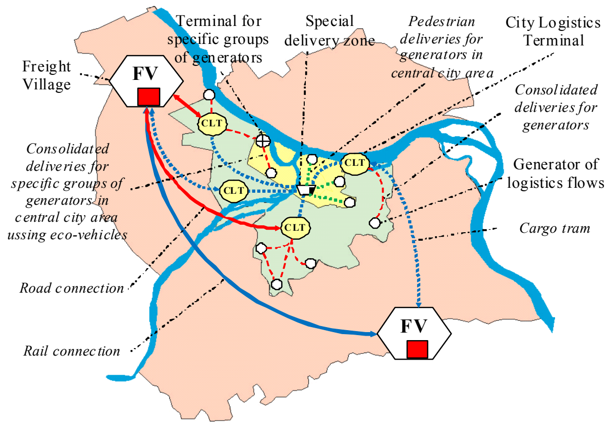

Figure 4. The CL3 concept

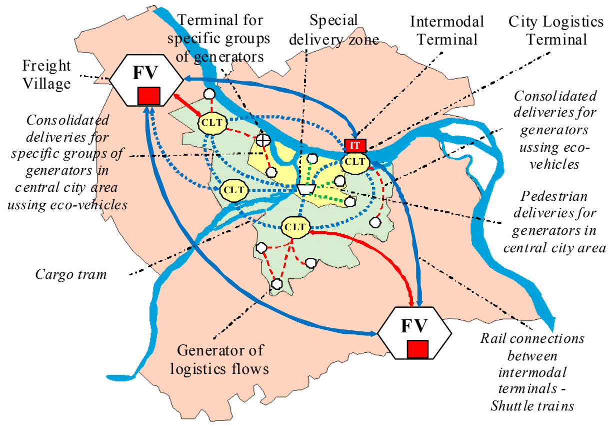

Figure 5. The CL4 concept

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

4. CONCEPTS EVALUATION CRITERIA

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

C1 - Investments for the concept development. Considering the least changes from the current situation, the CL1 concept requires the least investment. Investments for development of other concepts are significantly higher and depend on the micro-location, size and structure of the planned infrastructure.

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

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

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

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

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

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

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

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

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

5. EVALUATION OF CITY LOGISTICS CONCEPTS OF BELGRADE

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

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

Table 1. Fuzzy scale for criteria/concepts comparison

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

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

$$\ln \widetilde{a}_{ij} \approx (\ln l_{ij}, \ln m_{ij}, \ln u_{ij}),\ i,\ j = 1,2,...,\ n \qquad (1)$$

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

$$\mu_{ij}\left(\ln\left(\frac{w_i}{w_j}\right)\right) = \begin{cases} \dfrac{\ln(w_i / w_j) - \ln_{ij}}{\ln m_{ij} - \ln l_{ij}}, & \ln\left(\dfrac{w_i}{w_j}\right) \le \ln m_{ij}, \\ \dfrac{\ln u_{ij} - \ln(w_i / w_j)}{\ln u_{ij} - \ln m_{ij}}, & \ln\left(\dfrac{w_i}{w_j}\right) \ge \ln m_{ij}, \end{cases} \qquad (2)$$

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

It is necessary to find a crisp priority vector to maximize the minimum membership degree: $\lambda = \min\{\mu_{ij}(\ln(w_i / w_j)) | i = 1,..., n-1; j = i+1,..., n\}$.

The resultant model can be constructed as:

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

or

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

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

$$\ln w_i - \ln w_j - \lambda \ln(m_{ij} / l_{ij}) + \delta_{ij} \ge \ln l_{ij}, i = 1,..., n-1; j = i+1,..., n,$$

$$-\ln w_i + \ln w_j - \lambda \ln(u_{ij} / m_{ij}) + \eta_{ij} \ge -\ln u_{ij}, i = 1,..., n-1; j = i+1,..., n.$$

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

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

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

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

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

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

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

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

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

Table 2. Pair-wise comparison and criteria weights

Crit.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	w_i
C_1	/	MP	EI	QP	QP	VP	VP	AP	AP	MP	0,335
C_2	-	/	-	MP	MP	QP	QP	VP	VP	EI	0,112
C_3	-	MP	/	QP	QP	VP	VP	AP	AP	MP	0,335
C_4	-	-	-	/	-	MP	MP	QP	QP	-	0,037
C_5	-	-	-	EI	/	MP	MP	QP	QP	-	0,037
C_6	-	-	-	-	-	/	EI	MP	MP	-	0,012
C_7	-	-	-	-	-	-	/	MP	MP	-	0,012
C_8	-	-	-	-	-	-	-	/	EI	-	0,004
C_9	-	-	-	-	-	-	-	-	/	-	0,004
C_{10}	-	-	-	MP	MP	QP	QP	VP	VP	/	0,112

Table 3. Concepts comparison by criteria

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

Table 4. Preference values and concepts ranking

Criterion	Weight	CL1	CL2	CL3	CL4
C_1	0,335	0,682	0,227	0,045	0,045
C_2	0,112	0,708	0,236	0,047	0,009
C_3	0,335	0,001	0,012	0,104	0,882
C_4	0,037	0,001	0,012	0,882	0,104
C_5	0,037	0,001	0,012	0,104	0,882
C_6	0,012	0,001	0,012	0,104	0,882
C_7	0,012	0,001	0,012	0,104	0,882
C_8	0,004	0,001	0,012	0,104	0,882
C_9	0,004	0,654	0,160	0,160	0,027
C_{10}	0,112	0,012	0,090	0,449	0,449
Preference value		0,312	0,118	0,146	0,424
Rank		2	4	3	1

6. CONCLUSION

The current situation in Belgrade, in terms of logistics is critical. The problems are various and significant, logistics activities are carried out routinely and inefficient, and none of the participants take significant initiatives. There are no planning activities, comprehensive and long-term policy of city logistics. Urban planners' decisions are often inadequate, without analysis and overview of different measures and influences.

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

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REFERENCES

[1] Zečević, S., Kilibarda, M., Radivojević, L. & Tadić, S., 2002. City logističke koncepcije. In *Prilog unapređenju teorije i prakse planiranja i implementacije*, Institut za arhitekturu i urbanizam Srbije, 251-259

[2] Tadić, S., Zečević, S., Krstić, M., 2013. Lociranje City logističkog terminala primenom fazi AHP analize – primer Beograda. Tehnika - Saobraćaj, 60, 707-716.

[3] Statistički godišnjak Beograda 2011, dostupan na: https://zis.beograd.gov.rs/upload/G_2011S.pdf

[4] Saaty, T.L., 1980. The Analytic Hierarchy Process. New York, NY: McGraw-Hill International.

[5] Van Laarhoven P.J.M., Pedrycz W., 1983. *A fuzzy extension of saaty's priority theory*. Fuzzy Set and Systems, 11, 29–41.

[6] Wang, Y.M., Chin, K.S., 2011. *Fuzzy analytic hierarchy process: A logarithmic fuzzy preference programming methodology*. International Journal of Approximate Reasoning, 52, 541–553.

[7] Mikhailov, L., 2003. *Deriving priorities from fuzzy pairwise comparison judgments*. Fuzzy Sets and Systems, 134, 365-385.