SUSTAINABILITY OF THE CITY LOGISTICS INITIATIVES

Snežana Tadić [a], Slobodan Zečević [a], Mladen Krstić [a,*]

[a] University of Belgrade, Faculty of Transport and Traffic Engineering, Logistics Department

Abstract: *Problems and complexity of logistics in the urban areas caused the development of different initiatives, i.e. concepts of city logistics which should enable mobility and sustainable development. However, their sustainability depends on the degree of acceptance and interest of the key actors. For this reason, it is important to identify the problems and assess the impacts of solutions on all stakeholders. The absence of these analyzes may result in incorrect effects assessment and selection of unsustainable solutions. This paper performs the ranking of the sustainable infrastructure city logistics initiatives. Evaluation criteria weights are obtained by applying the fuzzy Delphi method, and the ranking of initiatives is obtained by applying the fuzzy VIKOR method.*

Keywords*: city logistics, initiatives, sustainability, stakeholders, multi-criteria decision-making.*

1. INTRODUCTION

With the growth of the world population, urbanization, flows of goods and unsustainable impacts of their implementation on the environment, the interest in city logistics also grew. In order to reduce the negative impacts of logistics activities on economic development and living conditions in the city, various measures, initiatives and concepts of city logistics are developed and tested. All solutions require larger or smaller changes of the system actors' behavior, and successful implementation and sustainability depend on the degree of acceptability by all stakeholders, i.e. analysis of the impact on the entire city logistics system. Such analyzes require a certain level of knowledge about the logistic activities' nature, which is usually not the case (Tadić & Zečević, 2015a). This paper performs the ranking of sustainability of the infrastructure city logistics initiatives that change the existing context of the urban environment. Fuzzy Delphi method is used to obtain the criteria weights, and fuzzy VIKOR for evaluating and ranking the initiatives.

2. RANKING OF THE CITY LOGISTICS INITIATIVES SUSTAINABILITY - PROBLEM STRUCTURE

City logistics initiatives can be structured by various criteria (Tadić & Zečević, 2016b). According to the required changes, they can be divided into initiatives without significant changes in the context of the urban environment (aimed at refurbishment) and those with radical changes. This paper deals in more details with the initiatives related to the infrastructure, as the initiatives that change the existing context of the urban environment (Tadić & Zečević, 2016a, Tadić, et al., 2014). The following describes the initiatives and criteria for evaluating the success of the initiatives.

* m.krstic@sf.bg.ac.rs

2.1 City logistics initiatives

Logistics centers (I_1). This type of initiative includes the use of the appropriate structures (centers) to consolidate transport flows and merge transport activities within the given area, i.e. city. Logistics centers are founded on traffic-favorable locations on the periphery of the cities or within the urban areas itself and they connect the inbound/outbound flows, i.e. they coordinate the flows of supplying and extracting the goods to/from the urban areas. Depending on the size and characteristics of the cities, the number, size, functions and locations of the logistics centers vary. The basic idea of the logistics, i.e. consolidation centers is the separation of the freight transport flows into two parts: flows within the urban area or the city and flows outside the area or the city. By applying this initiative, the implementation of inefficient transport activities in the city is avoided, the loading factor is increased and the number of vehicles in the central city parts, congestion on the streets, the fuel consumption and all negative impacts on the environment (air pollution, noise, vibration etc.) are reduced, while the quality of life in the urban areas is increased. In addition, the initiative of logistics, i.e. consolidation centers allows the use of more environmentally friendly vehicles for the final deliveries to the users and increase the positive effects in terms of the environment and society. Application of the advanced information and communication technologies enables better planning and implementation of the logistics operations and improves inventory control, product availability and customer service. On the other hand, better control and visibility of the supply chain enables the transformation from the pulled into pushed flows. Likewise, the concentration of the flows enables the offer of various VAL (Value Added Logistics) services, while the concept enables the reduction of the delivery costs and better resource utilization in the delivery points (Roca-Riu & Estrada, 2012, Tadić & Zečević, 2016a, Tadić, et al., 2014). However, despite a number of advantages, this type of initiative has certain disadvantages. The investments may be relatively high, especially in the initial phase of the logistics center construction and establishment of the consolidated delivery. Beside the investments, the operating costs of the center can be quite high as well. Many studies have shown that the cost of delivery increases as a result of additional steps in the supply chain, i.e. an additional transshipment of goods. Also, this initiative causes the loss of the direct contact between the shipper and receiver, and there is also a possibility of a monopolistic situation which eliminates the competition (Tadić & Zečević, 2015b).

Underground logistics systems (I_2). They belong to the group of the most radical and financially demanding city logistics initiatives. The initiative seems very innovative, considering the complicated system of underground networks, the amount of investment and a high degree of automation. The negative effects of logistics and freight transport in the city can be almost completely eliminated by the development and implementation of the underground logistics systems. In addition to the significant environmental and social benefits (increase of the city attractiveness and the reduction of the traffic congestion, energy consumption, emissions and noise, etc.), better management and improvement of the delivery performance (faster and more reliable deliveries, lower costs and greater safety and security of the deliveries, etc.) can also be achieved by applying the dedicated infrastructure and automated systems (Egbunike & Potter, 2011, Howgego & Roe, 1998, Tadić & Zečević, 2016a). However, these effects are achieved with very high start-up costs. In addition, there is no clear position on the mode and form of the stakeholders' engagement and who would be responsible for the functioning of the system. The most important observation is that such systems are possible only with significant government subsidies. (Egbunike & Potter, 2011) There are also big risks in the development of underground logistics systems, such as the collapse or damage to the historic city center, the unknown operation and maintenance costs of the system and the methods of financing, problems of the technology acceptance, the ability to connect with the intermodal transport flows, the lack of support for the acceptance of the system (insufficient government support), design and construction problems, competition with the conventional modes of transport (Egbunike & Potter, 2011), as well as other risks that are difficult to assess.

Standardization of loading units (I_3). Development and application of standardized loading units for the distribution of goods has been fueled by the success of the overseas containers.

Loading/unloading operations take a significant portion of the time and cost structures in the transport chain, particularly in the final distribution of the goods. These processes can be significantly faster and cheaper if the standard logistics units and equipment for vehicle loading/unloading is used (Dell' Amico & Hadjidimitriou, 2012, Jahre & Hattelan, 2004). Various units are used in the logistics flows. Larger units (containers, swap bodies) are used in the macro-distribution flows, while smaller logistic units (mini containers, logistics boxes, pallets, parcels and manufacturing or packaging units) dominate in the micro-distribution. The aim is to set the standards for a limited number of units (ideally one), with similar requirements towards the handling and transport equipment, which will be accepted by all actors of the city logistics chains. The development of the units is not a difficult task, but their standardization and wider application is (Jahre & Hattelan, 2004). Studies have shown that the use of standardized units increases the level of service, and reduces the emission of gases, energy consumption, traffic congestion and damage to the urban structures (Dell' Amico & Hadjidimitriou, 2012). It also leads to the increase of accessibility, transport efficiency and reduction of logistics costs. The main problems are the large initial investment costs for the companies that decide to implement the units, as well as their mass application. A possible way to overcome these problems would be the initiative by the big, important actors which would together have the potential to impose the certain loading unit as a standard for the market (Tadić & Zečević, 2016a, Tadić, et al., 2014).

2.2 Criteria for the evaluation of the city logistics initiatives

Fifteen criteria, divided into 4 groups: technical, social, economic and environmental, are defined for the evaluation of the described initiatives. The criteria are described in the Table 1

Table 1. Criteria for the evaluation of the city logistics initiatives

Criterion	**Definition**
- Technical criteria	
Service quality (**C_1**)	Customer satisfaction change as a result of the increased service quality.
Loading factor (**C_2**)	Vehicle's cargo space utilization change.
Customer coverage (**C_3**)	The possibility of serving a larger number of users in a particular geographic area.
Trip effectiveness (**C_4**)	Effectiveness change in terms of number of deliveries, distance, time of transport, reliability, etc.
Delivery size (**C_5**)	Changes in the amount of cargo handled during the deliveries.
- Social criteria	
Mobility (**C_6**)	Changes of the mobility of passenger and commercial vehicles in the city.
Accessibility (**C_7**)	Changes in access to the shipping/receiving locations.
Freeing of public spaces (**C_8**)	The possibility of freeing the public spaces.
Accidents (**C_9**)	Changes in the share of accidents caused by the delivery vehicles.
- Economic criteria	
Revenues (**C_{10}**)	Revenues generated by the delivery service.
Costs (**C_{11}**)	Costs of implementing the initiative and the operating costs.
- Environmental criteria	
Energy conservation (**C_{12}**)	Reduction in consumption of fossil fuel by transportation resources.
Congestion (**C_{13}**)	Changes in the traffic congestions in the city.
Air pollution (**C_{14}**)	Changes of the greenhouse gasses and particle emissions into the air.
Noise, vibrations (**C_{15}**)	Changes in the noise and vibration emissions.

3. CITY LOGISTICS INITIATIVES EVALUATION

For the evaluation of the city logistics initiatives a model that combines fuzzy Delphi and fuzzy VIKOR methods is used in this paper. Fuzzy extensions of the Delphi and VIKOR methods is used due to the linguistic evaluations, i.e. ambiguity and vagueness in the decision makers' thinking. Fuzzy Delphi method is used for obtaining the criteria weights, and fuzzy VIKOR for ranking the initiatives. In order to obtain the criteria weights it is first necessary to evaluate the criteria in relation to the stakeholders: residents, shippers/receivers, logistics providers and city administration. Linguistic scale that can be transformed into triangular fuzzy numbers (Table 2) is used for the evaluations.

Table 2: Linguistic terms and corresponding fuzzy values

Linguistic term	Abbreviations	Fuzzy scales
None	N	(1, 1, 2)
Very Low	VL	(1, 2, 3)
Low	L	(2, 3, 4)
Fairly Low	FL	(3, 4, 5)
Medium	M	(4, 5, 6)
Fairly High	FH	(5, 6, 7)
High	H	(6, 7, 8)
Very High	VH	(7, 8, 9)

After the criteria evaluation, the unification of the evaluations is performed using the equation (Hsu & Yang, 2000):

$$\tilde{w}_j = (\alpha_j, \beta_j, \gamma_j) \tag{1}$$

$$\alpha_j = \underset{h}{Min}(l_{jh}), \ j = 1,...,n; \ h = 1,...,o \tag{2}$$

$$\beta_j = \left(\prod_{h=1}^{o} m_{jh} \right)^{1/o}, \ j = 1,...,n; \ h = 1,...,o \tag{3}$$

$$\gamma_j = \underset{h}{Max}(u_{jh}), \ j = 1,...,n; \ h = 1,...,o \tag{4}$$

where α_j, β_j and γ_j are lower, medium and upper values of the unified fuzzy evaluation $\tilde{w}_j$, respectively, and $\alpha_j \le \beta_j \le \gamma_j$. l_{jh}, m_{jh} and u_{jh} are lower, medium and upper values of the triangular fuzzy evaluation which indicate the importance of the criteria *j* in relation to the stakeholder *h*. *n* is the number of criteria and *o* is the number of stakeholders. For obtaining the final values of the criteria weights it is necessary to deffuzify the values $\tilde{w}_j$ using the equation:

$$P(w_j) = (\alpha_j + 4\beta_j + \gamma_j)/6 \tag{5}$$

Stakeholders' evaluations are unified using the equations (1)-(4) and defuzzyfied using the equation (5), and then normalized using the equation:

$$w_j' = w_j \Big/ \sum_{j=1}^{n} w_j \tag{6}$$

Stakeholders' evaluations, unified, defuzzyfied and normalized values are given in Table 3.

Table 3. Criteria evaluations and final values of the criteria weights

Criterion	Residents	Shippers/Receivers	Providers	Administration	$\tilde{w}_j$	w_j	w_j'
C_1	VH	VH	VH	H	(1.20, 1.89, 2.70)	1,91	0,077
C_2	FH	FH	VH	H	(1.00, 1.64, 2.70)	1,71	0,069
C_3	FH	FH	H	FH	(1.00, 1.52, 2.40)	1,58	0,064
C_4	FH	VH	VH	M	(0.80, 1.62, 2.70)	1,66	0,067
C_5	M	VH	VH	M	(0.80, 1.54, 2.70)	1,62	0,065
C_6	VH	FH	H	VH	(1.40, 1.76, 2.40)	1,81	0,073
C_7	VH	H	H	FH	(1.00, 1.70, 2.40)	1,70	0,069
C_8	VH	M	M	H	(1.20, 1.49, 1.80)	1,50	0,061
C_9	VH	M	H	VH	(1.20, 1.68, 2.40)	1,72	0,070
C_{10}	M	H	VH	FH	(0.80, 1.56, 2.70)	1,63	0,066
C_{11}	FH	H	H	H	(1.00, 1.64, 2.40)	1,67	0,067
C_{12}	FH	M	FH	VH	(1.00, 1.50, 2.10)	1,52	0,062
C_{13}	H	FH	M	VH	(1.20, 1.56, 2.10)	1,60	0,065
C_{14}	H	FH	M	VH	(1.20, 1.56, 2.10)	1,60	0,065
C_{15}	H	M	M	VH	(1.20, 1.49, 1.80)	1,50	0,061

After obtaining the criteria weights, the evaluation of the initiatives in relation to the criteria is performed using the fuzzy VIKOR method (Opricovic, 2011). First, the fuzzy preference matrix is formed ($\widetilde{D}$) elements of which are $\widetilde{f}_{kj} = (l_{kj}, m_{kj}, u_{kj})$ triangular fuzzy evaluations of the alternative I_k in relation to criterion C_j (Table 4).

Table 4. Evaluation of the city logistics initiatives in relation to criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
I1	H	H	FH	VH	VH	FH	FH	M	M	FH	FL	FH	FH	FH	FH
I2	FH	FH	VL	FH	FL	VH	VH	VH	H	FL	N	VH	VH	VH	VH
I3	VL	FL	VH	FL	FH	L	L	VL	VL	VL	VH	FL	M	FL	FL

The ideal $\widetilde{f}_j^* = (l_j^*, m_j^*, u_j^*)$ and the nadir $\widetilde{f}_j^\circ = (l_j^\circ, m_j^\circ, u_j^\circ)$ values of the criterion functions, representing the evaluations of the initiatives in relation to criteria are obtained>

$$\widetilde{f}_j^* = \max_k \widetilde{f}_{kj}, \quad \widetilde{f}_j^o = \min_k \widetilde{f}_{kj} \tag{7}$$

Values of the normalized fuzzy difference $\widetilde{d}_{kj}$ are obtained afterwards:

$$\widetilde{d}_{kj} = \frac{\widetilde{f}_j^*(-)\widetilde{f}_{kj}}{u_j^* - l_j^\circ} \tag{8}$$

Maximum group utility $\widetilde{S}_k$ and minimum individual regret $\widetilde{R}_k$ are then obtained:

$$\widetilde{S}_k = \sum_{j=1}^{n} w_j{'}(\times)\widetilde{d}_{kj} \tag{9}$$

$$\widetilde{R}_k = \max_j w_j{'}(\times)\widetilde{d}_{kj}\,. \tag{10}$$

Based on them, the overall distances of the alternatives from the ideal solution $\widetilde{Q}_k$ are obtained:

$$\widetilde{Q}_k = v\frac{\widetilde{S}_k(-)\widetilde{S}^*}{S^{\circ u} - S^{*l}}(+)(1-v)\frac{\widetilde{R}_k(-)\widetilde{R}^*}{R^{\circ u} - R^{*l}}, \tag{11}$$

where $\widetilde{S}^* = \min_k \widetilde{S}_k$, $S^{\circ u} = \max_k S_k^u$, $\widetilde{R}^* = \min_k \widetilde{R}_k$, and $R^{\circ u} = \max_k R_k^u$. The *v* represents "the majority of criteria" strategy weight. By applying the equation (5) the values $\widetilde{S}_k$, $\widetilde{R}_k$ and $\widetilde{Q}_k$ are defuzzyfied. The ranking of the initiatives is performed according to the ascending crisp values (Table 5).

Table 5. Results of the fuzzy VIKOR method

		I1	*I2*	*I3*
$\widetilde{S}$	**S^l**	-0,092	-0,093	0,255
	S^m	0,221	0,220	0,567
	S^u	0,533	0,524	0,880
	Crisp S	0,221	0,218	0,567
	Rank	2	1	3
$\widetilde{R}$	**R^l**	0,017	0,042	0,033
	R^m	0,034	0,059	0,055
	R^u	0,052	0,067	0,077
	Crisp R	0,034	0,058	0,055
	Rank	1	3	2
$\widetilde{Q}$	**Q^l**	-0,316	-0,304	-0,140
	Q^m	0,001	0,012	0,179
	Q^u	0,321	0,324	0,502
	Crisp Q	0,001	0,012	0,180
	Rank	1	2	3

The initiative $I^{(1)}$ is proposed as the compromise solution since it was ranked as the first in relation to the *Q*, and both conditions were satisfied: **(Co.1.)**: *Adv* ≥ *DQ* where

$Adv = \left[Q\left(I^{(2)}\right) - Q\left(I^{(1)}\right)\right] / \left[Q\left(I^{(m)}\right) - Q\left(I^{(1)}\right)\right]$ and $DQ = 1/(m-1)$; (**Co.2.**): Alternative $I^{(1)}$ was also best ranked according to the *R*.

4. CONCLUSION

Solving the problems of city logistics depends on the selection and application of the appropriate initiatives in the given circumstances. When selecting the initiative one must take into account the vast number of criteria, which is the reason why this paper used the fuzzy Delphi method for obtaining the criteria weights and fuzzy VIKOR method for ranking the initiatives. The applicability of the model is demonstrated by ranking the infrastructure initiatives. Future research could be related to ranking and selecting initiatives belonging to some other groups.

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