LOCATING A HUMANITARIAN LOGISTIC CENTER: CASE OF SERBIA

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Abstract: *Nowadays life is becoming unpredictable regarding nature control and potential ecological problems. In situations when a natural disaster overpowers the human mechanism of defense, readiness for a fast reaction is the key. An extremely influential alleviation factor of disaster consequences is an adequate realization of logistic activities which in large depends on the location of the humanitarian logistic center. This task has strategic proportions and represents a potential issue while providing first aid to threatened parts if the solution is not optimal. Locating the humanitarian logistic center is a complex issue and involves considering various alternatives and criteria for its valuation, therefore multi-criteria decision-making methods are used. In this paper, the location of the humanitarian logistic center in Serbia has been considered on the territory of Novi Sad, Belgrade, Kragujevac, and Niš. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) method is used for problem-solving. By processing the data and comparing alternatives according to the relevant criteria, Belgrade has been determined as the optimal location of the humanitarian logistic center for the case of Serbia.*

Keywords*: humanitarian logistics, logistics center location, multi-criteria decision-making, PROMETHEE.*

1. INTRODUCTION

Logistics is present in all economic and social activities, but it is also an integral part of everyday life. Increased interest in logistics and its application has led to a myriad of definitions and different interpretations of the concept of logistics. Most definitions of logistics include that it is the process of planning, designing, modeling, projecting, controlling, and managing processes and systems that enable the flow of materials, products, energy, information, people, and money (Kilibarda, 2012). In short, logistics include all systems and processes which enable material and non-material flows (Zečević,

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2006). In logistics, the main goal is to provide required goods on the market at the right time, at the right place, in the right quantity, with the highest level of service, and at the lowest possible cost using the available resources and human resources. Thus, logistics is a particularly important function in emergencies, where it is necessary to quickly provide aid to the vulnerable and provide goods to prevent and mitigate the consequences.

In 2021, the Center for Research on the Epidemiology of Disasters (CRED) reported 432 catastrophes related to natural hazards worldwide (EM-DAT, 2022). There were 10,492 deaths, 101.8 million people were affected, and about $252.1 billion in economic losses. Compared with the average of 357 catastrophes per year, for the period 2001-2020, the number of recorded catastrophic events in 2021 is considerably higher. Floods dominated these events, with 223 occurrences in comparison to an average of 163 per year during the period 2001-2020. The number and impact of natural and man-made disasters worldwide have significantly increased in the past decade, showing a growing trend. Humanitarian logistics should suppress the effects of natural disasters, as well as problems caused by human factors. A well-organized and efficient logistical support system is essential when providing assistance in emergencies or after disasters. The effectiveness of humanitarian aid largely depends on humanitarian logistics. Locating the Humanitarian Logistics Center (HLC) stands out as one of the significant factors in achieving the efficiency of humanitarian logistics.

This paper aims to emphasize the importance of appropriately locating the humanitarian logistics center for the territory of Serbia and defining the methodology for that procedure. After described characteristics of humanitarian logistics and the significance of HLC locating, a description of the multi-criteria decision-making method PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is given in chapter 2, and it is used for the selection of location for the humanitarian logistic center. In chapter 4, criteria are evaluated and the multi-criteria issue of HLC location selection for the territory of Serbia is resolved. At the end of the paper, final conclusions and possible directions for future research are given.

2. HUMANITARIAN LOGISTICS - BACKGROUND OF THE PROBLEM

Logistics is defined as the part of the supply chain process that deals with the planning, implementation and control of efficient and effective flow and storage of goods, services and information, from the point of origin to the point of consumption, to meet customer needs (Council of Logistics Management, 1998). Humanitarian logistics is a special area of logistics whose main goal is to provide aid to people in need during emergencies or natural disasters and to prevent or mitigate their consequences. Although there are many interpretations of the term humanitarian action, three widely accepted principles - humanity, neutrality and impartiality - must be present for an action to be considered humanitarian (Tomasini and Van Wassenhove, 2009). The principle of humanity indicates that human suffering should be resolved wherever it is encountered. According to the principle of neutrality, assistance should be given without bias or belonging to a particular party to the conflict, while the principle of impartiality indicates that assistance should be given without discrimination, with priority being given to those in greatest need. The term humanitarian logistics refers to the planning, implementation and control of efficient and economical movement and storage of goods, materials, and information from the place of origin to the place of consumption, in order to alleviate the suffering of vulnerable people (Tomas and Kopczak, 2005).

There is a natural disaster in some parts of the world almost every single moment - fires, floods, tornadoes, earthquakes, tsunamis, etc. However, human factors can also cause catastrophes, such as war, terrorism, hazardous waste leaks, refugee crises, and so forth. The purpose of humanitarian aid is to provide food, water, medicine, shelter, and supplies to areas affected by large-scale emergencies (Beamon and Balcik, 2008). Logistics actually serves as a link between disaster readiness and response (Thomas, 2003). Procurement and transport in a logistical function are often one of the most expensive aspects of aid operations (Thomas and Kopczak, 2005).

2.1 Characteristics of humanitarian logistics

Humanitarian organizations find it difficult to achieve their goals due to a lack of customer pressure (Tomasini and Van Wassenhove, 2009). As natural disasters are unpredictable, the demand for goods is also unpredictable in terms of time, location, species, and size (Cassidi, 2003; Murray, 2005; Roh, 2012). Therefore, it is difficult to rely on information for humanitarian relief supply chains (Beamon and Balcik, 2008). The main characteristics of humanitarian logistics are impudence and insecurity. It is possible to predict some crises in advance, but many happen without warning. Technology is becoming more advanced every day, which makes it easier to forecast natural disasters more accurately. The next characteristic is timeliness and urgency. Losses and severity after a disaster, are depended on the speed of humanitarian logistics (Kušter, 2021) Time delays can lead to loss of life (Roh, 2012). Additional characteristic is poor economic efficiency. In disasters, the safety of people and their property is the number one prioritiy, while economic issues and costs are secondary. There are four phases of humanitarian logistics: preparation, reaction, recovery, and mitigation (Kilibarda, 2012). The first phase is the preparation phase which includes the procurement, allocation and storage of supplies and the design of an efficient logistics structure. The location of the humanitarian logistics center is characteristic of this phase. The reaction phase occurs after a crisis event. In this phase, the activities are focused primarily on saving lives and preventing major consequences. This phase is considered the most important as the speed of reaction depends on the consequences of a catastrophe or an extraordinary event. The last phase refers to providing the necessary aid in order to achieve the pre-accident state. The characteristics that distinguish humanitarian logistics from traditional logistics are unpredictability, uncertainty, and unconventionality. Furthermore, strategic goals, user and demand characteristics, and environmental factors are distinguished as well (Balcik and Beamon, 2008). Humanitarian logistics is funded by the public sector and charitable donations, whereas traditional logistics derives its revenue from the sale of products and services to customers. In humanitarian logistics, the motivation is not profit, and the goal is not to reduce costs but to increase the efficiency of activities (Roh, 2012).

2.2 The importance of locating a humanitarian logistics center

When a disaster occurs, humanitarian organizations can procure aid supplies from three main sources: local suppliers, global suppliers, and humanitarian logistics centers (Balcik and Beamon, 2008). In the early phases of a disaster, most of the critical supplies arriving in affected areas come from humanitarian logistics centers where supplies are pre-positioned (Balcik and Beamon, 2008). Costs are the main reason for pre-positioning supplies, as it is possible to purchase supplies at a reasonable price (Salisbury, 2007). When disaster happens, demand for supplies increases dramatically, and suppliers will often raise their prices as a response to that (Beamon and Balcik, 2008). Pre-positioning

supplies is closely related to the preparation phase and provides a rapid response when a disaster occurs (Tatham and Kovacs, 2007). The primary purpose for establishing emergency supplies is to support life-saving operations during the first few days after a sudden onset disaster, providing the almost immediate delivery of necessary relief items (United Nations Humanitarian Response Depot - UNDHA, 1994).

The location of the humanitarian logistics center is of great importance since it determines the success of the prompt response to the following disaster. Selecting humanitarian logistic center location in humanitarian logistics has also attracted a great deal of attention from humanitarian organizations in recent years. The world's largest humanitarian aid organizations, such as the World Food Program (WFP), the International Federation of Red Cross and Red Crescent Societies (IFRC) and Action Against Action Against Hunger (AAH), have started deploying strategic pre-positioned warehouses worldwide – humanitarian logistics centers (Bolturk et al., 2016).

There are several challenges that need to be overcome in order to ensure the smooth flow of the relief logistics within humanitarian logistics centers. First, the difficulty in creating an effective pre-positioning plan includes uncertainty whether disasters will occur or not and, if they do, where they will occur and to what extent (Rawls and Turnquist, 2010). Although pre-positioned stocks in humanitarian logistics centers may be useful in some cases, their utility may be limited as they require significant financial investment (Chaikin, 2003). The challenge for logisticians consists of proposing the location of a humanitarian logistics center out of reach of the potential disaster, while at the same time ensuring sufficient disaster proximity to deliver aid quickly and efficiently (Balcik and Beamon, 2008). Therefore, locating a humanitarian relief logistics center is a complicated multi-criteria problem.

3. PROMETHEE METHOD

Multi-criteria decision-making (MCDM) methods mainly consist of two parts. The first part determines the weights of the criteria, and the second part evaluates the alternatives in relation to them. In this paper, the criteria weights are determined by decision square matrix. The importance of the criterion is assessed as follows: grade 1 is used when one criterion is more important or dominant in relation to another (if the criterion c_i is dominant, it receives a grade of 1, and the criterion c_j is a grade of 0); a score of 0.5 is used when the criteria are of equal importance, i.e. when there is no more dominant criterion; a grade of 0 is assigned to a criterion that is less important, i.e. which is inferior to the other criterion (if the criterion c_i is inferior, it receives a grade of 0, and the c_j criterion receives a grade of 1).

In this paper, the multi-criteria method PROMETHEE (Brans, 1982), more precisely PROMETHEE II, is used to solve the problem of selecting the best location. The essence of the PROMETHEE method is in determining the preference of each alternative compared to each other, according to each of the criteria, using the preference function in order to acquire the rank of alternatives, either partial or complete (Dimitrijević, 2017). One alternative dominates the other if it performs as good as the other on all criteria, and better than another by at least one criterion, which is expressed by the relation of preference. The relation between two equally good alternatives by all criteria, i.e. mutually equal alternatives, is expressed by the relation of indifference. When one alternative performs better on a criterion c_s and the other one is better on criterion c_r, it is impossible to decide which the best one without additional information is. Therefore

both alternatives are incomparable. The characteristic of the PROMETHEE method is the existence of six defined preference functions (Brans, 1982). It is used to reduce the difference in values for each pair of alternatives from 0 to 1, according to each criterion. Thus, it achieves both normalization of values in the matrix and obtaining information on the preference (dominance) of each alternative in relation to each on all the criteria. Further resolution procedure of multi-criteria task using the PROMETHEE method, is presented in algorithmic form.

Step 1. - *defining the mutual preference of alternatives*, $P(A_1,A_2)$, for each pair of alternatives from the set of alternatives A, in accordance with the selected types of preference functions and the parameters of these functions.

Step 2. - *forming the preference index for each pair of alternatives* according to the formula:

$$\pi(A_1, A_2) = \frac{W_j}{\sum_{j=1}^{n} W_j} \sum_{j=1}^{n} \left(W_j \cdot P_j(A_1, A_2)\right) \quad (1)$$

This characteristic shows the preference of alternative A_1 in relation to alternative A_2, though taking into account all the criteria at the same time, regardless $P_j(A_1,A_2)$, which also shows the preference of A_1 in relation to A_2, but only by j-criterion.

Step 3. - *forming the preference index matrix* (Table 1):

Table 1. *Preference index matrix*

	A_1	...	A_m
A_1		...	$\pi(A_1,A_m)$
⋮	⋮		⋮
A_m	$\pi(A_m,A_1)$	...	

Step 4. - *Calculating the positive* $\Phi^+(A_1)$ *and negative* $\Phi^-(A_1)$ *characteristics* for each alternative from set A:

$$\Phi^+(A_1) = \frac{1}{m-1} \sum_{x \in A} \pi(A_1, x) \quad (2)$$

$$\mathbf{\Phi}^{-}(\mathrm{A}_1) = \frac{1}{\mathrm{m}-1} \sum_{\mathrm{x} \in \mathrm{A}} \pi(\mathrm{x}, \mathrm{A}_1) \quad (3)$$

$\Phi^+(A_1)$ presents how much alternative A_1 is better than all other alternatives from the set of alternatives A, on all criteria from the set of criteria K. Logically, $\Phi^-(A_1)$, presents the opposite information, i.e. how much all other alternatives are better than alternative A_1.

Therefore, based on these characteristics, the final ranking of alternatives in relation to the total preference of alternative A_1 ($\Phi(A_1)$), can be calculated as follows:

$$\Phi(A_1) = \Phi^+(A_1) - \Phi^-(A_1). \quad (4)$$

According to the PROMETHEE II method, alternative A_1 is *preferable* to alternative A_2 if the following is fulfilled:

$$A_1 P^{II} A_2 \ \textit{if} \ \Phi(A_1) > \Phi(A_2) \quad (5)$$

Alternative A_1 is *indifferent* to alternative A_2 if:

$$A_1 I^{II} A_2 \ \ if \ \ \Phi(A_1) = \Phi(A_2) \tag{6}$$

4. CASE STUDY – LOCATION SELECTION OF HUMANITARIAN LOGISTIC CENTER IN SERBIA

When it comes to catastrophes that happened in Serbia, floods have the largest part. The last major floods in Serbia occurred in 2014. On that occasion, 22% of the population was affected and damages of 1.7 billion euros were caused. In 2006, about 225,000 hectares of fertile land were flooded, and the damage was estimated at 35.7 million euros. The biggest flood in Serbia happened in 1965, when the river Danube overflowed, which affected almost all river flows, and about 150,000 hectares of land, 16,000 houses and 214 kilometers of roads were under water. When it comes to earthquakes, the most devastating earthquake happened in Kraljevo in 2010, when 200 people were injured, while about 850 households were destroyed. Some of disasters that have impacted Serbia in previous years are fires, storms, and landslides. However, as the floods have caused the greatest damage so far, alternatives will be considered first in relation to the possibility of rivers overflowing.

4.1 Problem structure, criteria, and alternatives

The proposed model is used for the selection of humanitarian logistic center locations for the territory of Serbia. For HLC selection, the following criteria are selected: proximity to disaster-prone areas - c_1, availability of logistics experts - c_2, geographical characteristics - c_3, transport connectivity - c_4, availability of existing facilities and infrastructure - c_5, land price - c_6, number of logistics providers - c_7. In literature, proximity to disaster-prone areas is the most dominant factor when it comes to the location selection of humanitarian logistic centers (Roh, 2022). HLC location impacts directly the response time and costs of providing aid (Balcik i Beamon, 2008). The availability of logistics experts is another dominant factor that is related to the availability of trained and qualified staff. The quality of HLC functioning directly depends on knowledge and experts' qualifications. Geographical characteristics refer to the physical characteristics that describe the natural environment of the place (relief, rivers, climate, etc.). Transport connectivity implies the availability of transport infrastructure between the potential location of the HLC and the site of the disaster. It considers the existence and proximity of the airports and ports as well. Since the aim of humanitarian aid is to deliver humanitarian supplies as soon as possible to the users after the disaster, the availability of airports is an extremely important factor for emergency operations. The criterion related to existing facilities and infrastructure considers the existence of facilities that can be used for the purpose of storing humanitarian aid supplies, facilities that provide electricity, water, and vehicle maintenance services, and other facilities that support the work of HLC (Roh, 2022). Before locating the humanitarian logistics center, it is necessary to consider the proximity of regional logistics centers. Land price is one of the criteria that must be included in the cost analysis. The criterion of the presence of logistics providers is significant not only because of their existence but also because of the necessary cooperation between them.

The following cities in Serbia were chosen as potential locations of the humanitarian logistics center: Novi Sad - HLC_1, Belgrade - HLC_2, Kragujevac - HLC_3 and Niš - HLC_4. Novi Sad is extremely convenient from the aspect of transport connections, which is proved by

the fact that it is one of the most important hubs in Serbia, next to Belgrade and Niš. There is no airport in Novi Sad. The city is not risky in terms of environmental catastrophes, and it is more protected from earthquakes compared to other alternatives, hence there is a possibility of Danube overflowing. The largest hub of Serbia is Belgrade, which occupies the best transit position. The "Nikola Tesla" Airport in Belgrade has a large capacity and significantly affects the transport connections of this city. The buoyancy of rivers is excellent, but there is a risk of river overflow. A large number of residents are present, which is positively characterized. Thus, by locating a humanitarian logistics center in this city, help can be provided to a large number of people. The availability of logistics experts is advantageous in Novi Sad and Belgrade. The transport connection of Kragujevac does not reach the levels of transport connections of other alternatives, there are no waterways nor airport, but the airports in Belgrade, Kraljevo or Niš can be reached promptly. According to the criteria of land prices, location in Kragujevac is optimal. Niš has an excellent geoposition and is a great hub of Serbia. It has an airport that does not have a large capacity, though it is very busy and has a positive impact from the aspect of transport connections. From the aspect of proximity, it is favorable because it can cover risk areas from floods due to problems around the Morava and its tributaries. In addition, there is already a Serbian-Russian humanitarian center in Niš, which could provide the necessary support in case of need.

4.2 Determining criteria and evaluation alternatives

The criteria weights were determined by using a square matrix (Table 2)**.** According to the results, the dominant criterion is the proximity of the area of susceptible catastrophes (c_1) due to the fact that the factor of rapid response is crucial when acting in crisis situations. Furthermore, the most important criteria are the availability of logistics experts (c_2), transport connectivity (c_4) and the number of logistics providers (c_7).

Table 2. Weight coefficients of criteria decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	Σ
C_1	/	0.5	1	0.5	1	1	0.5	4.5
C_2	0.5	/	1	0.5	0.5	1	0.5	4
C_3	0	0	/	0.5	0.5	0.5	0	1.5
C_4	0.5	0.5	0.5	/	1	1	0.5	4
C_5	0	0.5	0.5	0	/	0.5	0.5	2
C_6	0	0	0.5	0	0.5	/	0	1
C_7	0.5	0.5	1	0.5	0.5	1	/	4

In relation to the criteria which the weights were obtained for, the alternatives are evaluated according to the criteria using the linguistic terms given in Table 3, where each term is assigned a numerical value, from 1 to 5.

Table 3. Criterion values and corresponding linguistic descriptions

Value	Linguistic term
1	Most unfavourable
2	Unfavourable
3	Medium favourable
4	Favourable
5	Most favourable

The evaluation of potential locations of the humanitarian logistics center is given in Table 4.

Table 4. Evaluation of potential HLC locations according to criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
	max	max	max	max	max	min	max
HLC_1	4	4	5	4	5	5	5
HLC_2	5	5	3	5	4	5	5
HLC_3	2	3	4	3	3	3	4
HLC_4	4	4	3	5	4	4	4

In order to solve the problem, the Visual PROMETHEE software tool was used, i.e. to determine the rank of potential locations based on the displayed data. Aiming to determine criteria for disaster-prone areas proximity, availability of logistics experts, transport connectivity and number of logistics providers, a linear preference function (V-shape) with parameter 2 was used, where preference is expressed in value between 0 and 1. Therefore, if the difference in the value of the HLC_i - HLC_j alternative is greater than 2, according to this criterion, then we prefer the HLC_i alternative (preference function equal to 1). If the difference HLC_i - HLC_j is between 0 and 2, the preference function takes a value between 0 and 1. Previously mentioned four criteria are the most important for the analysis, the application of the linear preference function takes into account the smallest deviation. For other criteria, a usual preference function is used, without parameters. For these criteria, the higher (the less) value, that is better for choosing the appropriate alternative for the maximization (minimization) type of criteria. The obtained results are shown in Table 5.

Table 5. Ranking potential locations using the Visual PROMETHEE tool

Location	Phi	Phi+	Phi-	Rank
HLC_2	0,3529	0,4902	0,1373	1
HLC_1	0,1716	0,3725	0,2010	2
HLC_4	0,1225	0,3235	0,2010	3
HLC_3	-0,6471	0,1176	0,1176	4

According to results, HLC_2 – Belgrade was obtained as the best alternative, while HLC_1 – Novi Sad was in second place. In order to avoid subjectivity in the evaluation of variants, it is necessary to do more iterations, i.e. to conduct sensitivity analysis. For this purpose, three more iterations were made. In the first iteration, all functions of preference are equalized, i.e. a simple preference function without parameters was chosen. In the second iteration, the weight coefficients are equal for all criteria, i.e. value 1 was taken for the weight of each criterion. In the last iteration, the preference functions and weight coefficients are equalized. The results are presented below. The results obtained in these iterations are shown in Tables 6, 7 and 8, respectively. It can be seen that in the first iteration the best alternative was HLC_2 – Belgrade, while in the second place is HLC_4 – Niš. In the second iteration the best is the first alternative HLC_1 – Novi Sad, while in the second place is HLC_2 – Belgrade. Finally, in the last iteration the best alternative is HLC_2 – Belgrade, and the other is alternative HLC_1 – Novi Sad. Having in mind all three iterations, the alternative HLC_3 – Kragujevac is the worst positioned.

Table 6. Results of iteration 1 using the Visual PROMETHEE tool

Iteration 1	Phi	Phi+	Phi-	Rank
HLC_2	0,5588	0,6961	0,1373	1
HLC_4	0,1176	0,4020	0,2843	2
HLC_1	0,0882	0,4510	0,3627	3
HLC_3	-0,7647	0,1176	0,8824	4

Table 7. Results of iteration 2 using the Visual PROMETHEE tool

Iteration 2	Phi	Phi+	Phi-	Rank
HLC_1	0,2222	0,4444	0,2222	1
HLC_2	0,0833	0,3611	0,2778	2
HLC_4	0,0556	0,3333	0,2778	3
HLC_3	-0,3611	0,2778	0,6389	4

Table 8. Results of iteration 3 using the Visual PROMETHEE tool

Iteration 3	Phi	Phi+	Phi-	Rank
HLC_2	0,2222	0,5000	0,2778	1
HLC_1	0,1667	0,5000	0,3333	2
HLC_4	0,0556	0,3889	0,3333	3
HLC_3	-0,4444	0,2778	0,7222	4

Based on the results, the conclusion is that in the case of Serbia, the best location for the humanitarian logistics center would be in Belgrade. Novi Sad, as the best in the second iteration and the second best in the third iteration, takes second place for the potential location of the HLC. Belgrade and Novi Sad are suitable primarily from the aspect of proximity to disaster-prone areas. Vojvodina is considered as one of the areas prone to floods, where in 1965 the largest flood in Serbia took place, it is close enough to Belgrade to react in case of new catastrophes. At the same time, Belgrade is far enough away from potential disaster. However, for the micro-location of the logistics center that would be located in Belgrade, it is necessary to take into account two large rivers - the Sava and the Danube. The micro-location of the humanitarian logistics center should be far enough distanced from the area that could be affected by the overflow of the previously mentioned rivers. On the other hand, their potential can be used to deliver large quantities of goods intended for humanitarian aid. Belgrade is interconnected with other Serbian cities which allows access to all parts of Serbia where disasters could potentially occur. The reason why Belgrade and Novi Sad stand out is the presence of logistics experts and the number of logistics providers who, through cooperation and adequate coordination, would be vitally important in providing humanitarian aid. The disadvantage is the price of the land. Belgrade is considered to be a area with the highest land prices, but the price in the case of providing assistance to the endangered is not the most relevant factor, but speed and efficiency.

5. CONCLUSION

The problem of locating the humanitarian logistics center is substantial and complex. The efficiency of providing humanitarian aid to a great extent depends on the location of the humanitarian logistics center. Immediate response in unexpected circumstances may be aided by the HLC location. In this paper, the multicriteria PROMETHEE method was used to rank and select the HLC location. The application of this method is presented in solving the case of Serbia. Due to the complexity of solving the problem of locating and the present uncertainty, it is necessary to consider several criteria and include expert opinion. Future research could relate to considering the micro-location of the center, considering several criteria, or involving more stakeholders in the decision-making process.

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