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DECISIONS ON THE LOGISTIC CENTERS LOCATION, CASE OF THE BALKAN PENINSULA

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Abstract**—**Integration of the Balkan Peninsula into modern logistic flaws of European supply chains represents one of the most important objectives of the countries which are situated in this area. This paper is focused on finding the most suitable locations for the logistic centers in the area of the Balkan Peninsula (BP). Strategic global logistic center location-allocation decisions involve many environmental factors that may be conflicting in nature, and can pose a difficult selection problem. Aiming at a more precise analysis of the environmental influence for finding suitable location of logistic centers, mathematical methods are used in this paper such as Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and Greedy heuristic algorithm as a support in making LC location decisions. Implementation of the Greedy heuristic algorithm into PROMETHEE improves the existing methodology for finding the most suitable location for logistic centers. Beside location selection, this is an illustrative method that evaluates logistical capabilities for individual countries on BP. The results, obtained by multi-criteria evaluation using presented method, gives the possibility of identification and evaluation of the most frequent logistic problems for each country separately.

Keywords**—**Multi-criteria decisions, PROMETHEE method, logistic competition.

I. Introduction

FOR over a century, new methods have been found and methodology for finding the most suitable location for factories, airports, warehouses, logistic centers (LC) has been improved. The quality of transport services and the total costs of transporting system depend on the position of important objects in the distribution network. The number and location of LC in the distribution network have a direct influence on the cost of the final product.

One of the crucial factors for a highly efficient distribution network is a suitable choice of LC location. The main aim of this paper is to find the most suitable location for the LC in the area of the Balkan Peninsula (BP) which would improve logistic flaws in distribution network between Central Europe and Asia Minor region. Between these two regions is the BP area, known in history to be the gate connecting eastern and western market but today BP is known by its insufficiently used geographical position in the global distribution network. Part of the reasons for insufficiently used geographical position on the BP are constant oscillation of environmental criteria (for example: safety, political stability, inflation, etc.), so the investors are reserved in making decisions about new LC.

Mathematical methods are used in this paper such as Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) [1] as a support in making LC location decisions. We use also Greedy heuristic algorithm [2] to support PROMETHEE method in order to obtain more accurate results. Greedy heuristic algorithm is used to find a suitable geographical position of LC, such that the average (total) distance traveled by those who visit or use these LC is minimized. In order to find a suitable LC location, it is necessary, beside geographical position which stands for one of the criteria, to analyze all important criteria that influence on location choice. PROMETHEE method is a method of multi-criteria decision-making problem, and it is applied in this research to analyze all important criteria which affect LC location decision.

II. Literature review

During the last three decades, a great number of methods that solve location problems have been developed. Depending on the complexity of the problem, the exact and heuristic methods can be distinguished. Implementation of exact methods for solving location problems is limited to relatively simple problems, while more complex problems can be solved using heuristic methods. Solutions for location problems are first mentioned by Weber [3], later, Cooper [4], [5] and in recent times, many other researchers found solutions and improved methods for solving location problems [6].

During creation of supply chain network, traditional solutions are done with the aim of minimizing supply costs of LC [7]. Drawback of this solution is the fact that in this case suppliers are given greater significance compared to consumers [8], so suppliers are given an advantage over consumers. Modern location solutions consider maximum profit increase of LC [9] with the focus shifted to consumers and meeting their needs [10], [11]. Beside that, researchers pay special attention to the effect of environmental complexity which has indirect influence on the existence of all participants (for example: LC, factories, distribution centers, warehouses…) in distribution network [12], [13].

Great deal of operational-strategy literature uses macro-institutionalized (environmental) criteria such as government rules, economic policy regulations, political stability, etc [14], [15] to evaluate and choose suitable location solutions. PROMETHEE I and PROMETHE II methods, invented by J. P. Brans [1], has been widely used in measuring environmental complexity. PROMETHEE I and PROMETHEE II methods are presented for the first time in 1982 at the conference “L'ingénièrie de la decision” organized at the University of Laval in Canada [1]. In the same year, several practical examples of application of the methods were presented by G. Davignon [16], and several years later, J.P. Brans and B. Mareschal developed PROMETHEE III and PROMETHEE IV methods [17, 18]. The same authors also suggested visual, interactive modulation GAIA, which represents a graphic interpretation of PROMETHEE method, and in 1992 and 1995, they suggested two more modifications – PROMETHEE V and PROMETHEE VI [19, 20]. Many successful implementations of PROMETHEE method into various fields are evident, and as such, these methods found their place in banking, investments, medicine, chemistry, tourism, etc [21].

Beside PROMETHEE method, many researchers have applied heuristic methods to solve location problems. Greedy heuristic algorithm [2] which was later efficiently applied by Whitaker [22] and Hidaka [23], has also been developed for solving location problems. In this paper, by implementing Greedy heuristic algorithm into PROMETHEE method, we have tried to give our contribution to solving location problem.

III. EUROPE AND BALKAN PENINSULA LOGISTICS OVERVIEW

The Europe enlargement, outsourcing in economy, development of LCs and their progressing towards Eastern European countries, as well as expansion of cargo flows between Western Europe and Asia, create new challenges for the BP region. As a consequence of permanently increasing cargo flows, there is a trend of building LCs to reduce transportation time and cost and to improve customer service. Georgijevic at al. [24], point to BP as the weakest link in the distribution network between Central Europe and Asia Minor region.

We confirmed this claim by graphic presentation of the present LCs situation in Europe and BP (figure 1).

Fig. 1 - Important LCs in Europe and ports in southern Europe – the basis of present logistic area model

The information necessary for creating map of LCs (figure 1.), was taken from published papers and projects which contributed to the development of LCs. So, the Center for Advanced Infrastructure and Transport [25] published a study in which all important LCs with a strong influence on global transport are described clearly and in detail. The project carried out under the European Commission (EC) called “Sutranet” [26], gave the list of the most influential LCs in Europe in the final report. Tiefensee [27] presented Germany as one of the most influential European countries in the field of logistics, where he emphasized its dominant geographical position. Also, in creation of LCs map in figure 1, information from famous logistic companies and their associations including European platforms, the association of European freight villages, Association of Spain Transport Centers (ACTE), the Association of Danish Transport Centers (FDT), the Association of German Freight Villages (DGG), and the Association of Italian Freight Villages (UIR), has been used.

Regarding the previously presented researches, Germany can be designated as the most advanced logistic country which has the most developed infrastructure with modern LCs. This outcome is also confirmed by Arvis at al. [28] who compared countries according to Logistics Performance Index (LPI). The LPI index was created to help countries to evaluate their logistic performance. On the basis of qualitative and quantitative indicators of LPI index, Germany is evaluated with the highest mark and represents the leading European country in the field of logistics, while the countries of the BP were among the least developed. Also, according to this research (figure 1), in the area of the BP, there are only a few moderately developed LCs, while none of them is on the list of the most influential in Europe. This way, the BP is completely omitted in distribution network between Central Europe and Asia region.

IV. METHODOLOGY

In this paper, the method for finding the most suitable location for LC on the BP is suggested. Many criteria affect LC location selection. One of the most influential criteria is also geographical position of LC. Geographical position of LC should be such that average (total) distance traveled between objects in distribution network is minimized. Greedy heuristic algorithm is used for minimization of average distance between objects. Since geographical position as one of criteria is not the only aspect that influences the decision making process when choosing the most suitable location of LC, the rest of the relevant criteria such as political stability, safety, legislation etc, must be taken into account. Using PROMETHEE method, the rest of the important criteria are taken into account and complex analysis is done. As a result the most suitable LC location is found.

4.1 Greedy heuristic algorithm

In order to transport goods through the BP with minimal costs, the LC would be located on the crossroads of railway, air and highway traffic. One way to measure the efficiency and effectiveness of LC is by evaluating the average distance between the customers and the LC. When the average distance decreases, the accessibility and response times of the LC increase. This is known as the p-median problem (PMP) [29]:

$$\min F = \sum_{i=1}^{n} \sum_{j=1}^{m} c_i \cdot d_{ij} \cdot x_{ij} \tag{1}$$

subject to:

$$\sum_{j \in J} x_{ij} = 1, \quad \forall i \in I \tag{2}$$

$$\sum_{j \in J} y_j = p, \quad \forall j \in J \tag{3}$$

$$x_{ij} \le y_j; \tag{4}$$

$$x_{ij} \in \{0,1\}; \quad y_j \in \{0,1\};$$

Where $I = \{1,\dots m\}$ is the set of demand locations; $J = \{1,\dots n\}$ is the set of candidate sites for LC, d_{ij} is the shortest distance between location i and location j, $x=1$ if the customer at location i is allocated to the LC at location j and 0 otherwise, $y_i=1$ if a LC is established at location j and 0 otherwise, p is the number of LC’s to be established and c_i is the population at the location i.

Most of the solution methods for PMP are heuristic. For solving PMP we used Greedy heuristic algorithm [2]. The Greedy heuristic algorithm starts with an empty set of LC, and then the first-median problem of n such problems is solved and added to this set. LC’s are then added one by one until the number p is reached; each time, the location which most reduces the total cost is selected [30]. An efficient implementation is given by Whitaker [22].

In this paper we assuming that each citizen in any country of BP has the same requirements for certain goods, then the number of requirements is proportional to the number of citizen’s c_i in each country of the BP. By applying Greedy heuristic algorithm the most suitable LC location (called Median) on the BP is selected. Median is determined by measuring total distance for all three types of transport (railway, air and highway) between cities on the BP. Candidate sites for LC locations are the capitals on the BP countries (figure 2). Within this research, we limit the set of possible solutions to the main cities of the BP. An illustrative example is also applicable to a wider set of solutions. The result in table 1 shows that the first median (highway traffic costs) is located in Sofia. This location is confirmed because transport costs per kilometer are the lowest in relation to other cities. During this analysis, distances between cities are measured only on highways. By air traffic analysis (figure 2), the distances between cities over air traffic routes are used as the criterion. The first median is also located in Sofia because transport costs per kilometer by plain are lowest. With railway traffic, the results of median analysis show that that the lowest costs of transport are in Bucharest. During this analysis, transport duration between cities is used, not the mileage as with other ways of transport. Railway transport duration between cities is obtained according to evidence of Serbian, Croatian, and Slovenian railways.

Table 1. Results of medians analysis

Higway		Air		Railway traffic	
City	Average Distance [km]	City	Average Distance [km]	City	Average travel hours [h]
Sofia	24,578,787,126.00	Sofia	18,989,051,188.00	Bucharest	444,734,646.40
Bucharest	26,805,108,891.00	Bucharest	20,012,436,329.00	Belgrade	454,358,671.90
Belgrade	28,002,852,065.00	Belgrade	20,168,268,645.00	Sofia	468,478,631.60
Skopje	29,842,982,765.00	Skopje	21,317,296,800.00	Zagreb	667,820,128.30
Thessaloníki	38,899,432,252.00	Podgorica	24,450,261,791.00	Skopje	747,587,911.55
Podgorica	39,485,353,082.00	Sarajevo	24,774,262,602.00	Thessaloníki	764,765,248.38
Sarajevo	39,584,770,220.00	Tirana	25,582,804,058.00	Ljubljana	768,385,119.57
Tirana	40,558,095,704.00	Thessaloníki	27,205,724,104.00	Sarajevo	802,227,665.00
Zagreb	43,932,252,157.00	Zagreb	34,255,049,950.00	Podgorica	916,842,621.18
Ljubljana	51,016,322,926.00	Ljubljana	40,523,567,077.00	Tirana	1,050,950,458.45

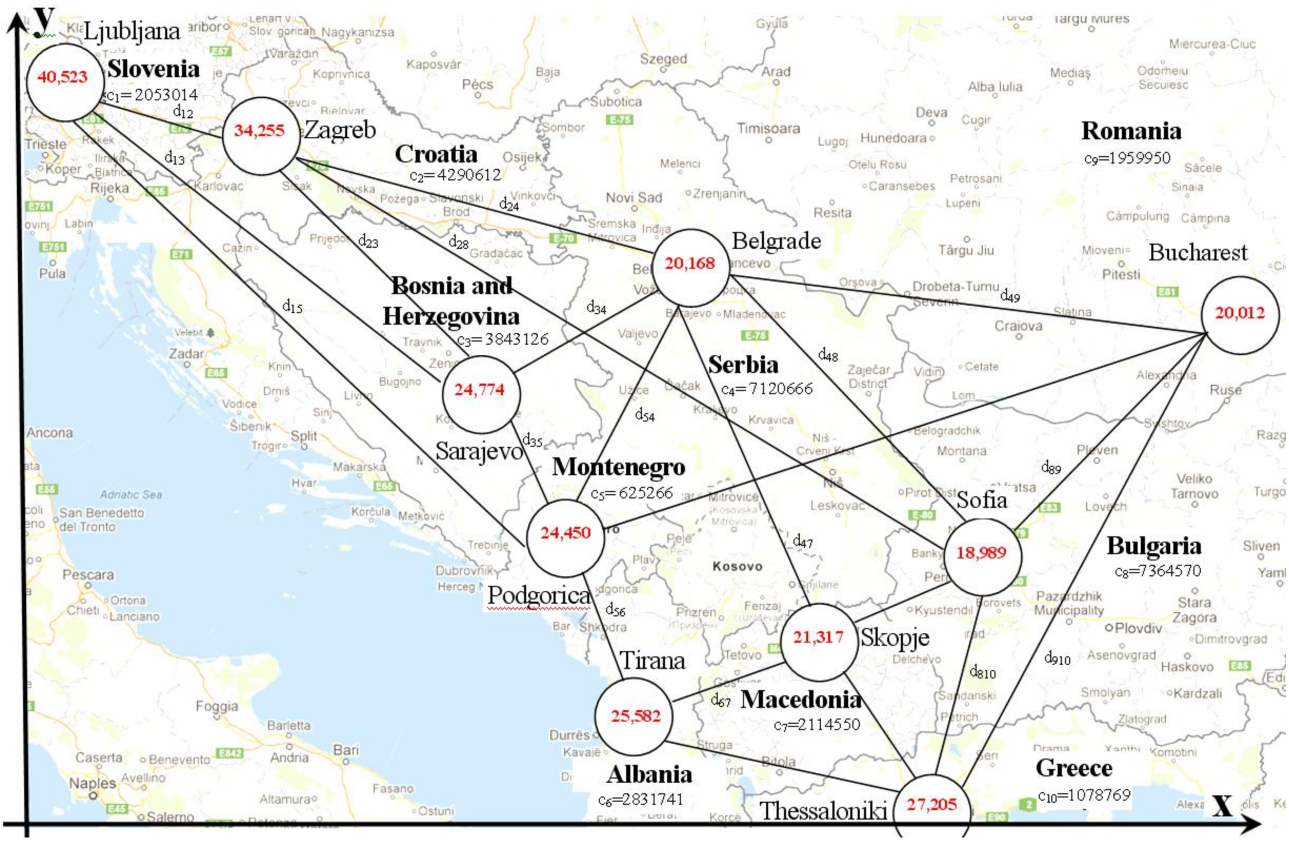

Figure 2. Graphical results (described in millions of km) on the example of air medians analysis

On the basis of those data, according to geographical parameters, the most suitable location for the LC is the city of Sofia which is situated on the crossroads of the main highway and air tracks. The lowest railway transport costs will be achieved if LC is located in Bucharest. On the basis of railway transport, the most suitable location for the LC is the city of Bucharest.

For final LC location decision, besides these criteria results about geographical position, additional analysis of all relevant criteria such as political stability, safety, legislation etc, must be taken into account. In further work, which combines both the Greedy heuristic algorithm and PROMETHEE II method, all important criteria that influence the choice of LC location on the

BP are taken into account. In this way, an efficient approach to selecting suitable LC location is obtained.

4.2. Mathematical model

PROMETHEE method is based on mutual comparison of each alternative pair with respect to each of selected criteria. In order to perform alternative ranking by PROMETHEE method, it is necessary to define preference function *P (a, b)* for alternatives *a* and *b* after defining criteria. Alternatives *a* and *b* are evaluated according to criteria functions. It is considered that the alternative *a* is better than alternative *b* according to criterion *f*, if *f (a) > f (b)*. Decision maker has possibility to assign the preference to one of the alternatives on the basis of such comparison. The preference can take values on the scale from *0* to *1*, and relation combinations are possible to present using following relations:

$P(a, b) = 0$ no preferences, indifference,
$P(a, b) \approx 0$ weak preference $k(a) > k(b)$,
$P(a, b) \approx 1$ strong preference $k(a) >> k(b)$,
$P(a, b) = 1$ strict preference $k(a) >>> k(b)$.

Relations have following limitations:

$$0 < P(a,b) > 1 \quad (1)$$

$$P(a,b) \neq P(b,a) \quad (2)$$

Higher preference is defined by higher value from the given interval. This means that, for each criterion, the decision maker considers certain preference function [31]. In fig. 3, six generalized criteria are given and six preference functions *P (d)*. All six generalized criteria are possible to illustrate via linear functions, that is, they are obtained by choosing the highest four points inside criteria space of the given criterion. In fig. 3, beside criteria functions, parameters for chosen points within criteria space, which is illustrated in x-axis, are given, and the level of preference is given in *y*-axis *(P)*. In the four-level criterion, instead of value $P(d) = ½$, it is possible to give any value $0 < P(d) < 1$.

In fig. 3, the following denotation is used: *m* – indifference limit, *n* – strong preference limit, *q* – approximate value between *m* and *n* for Gaus criterion.

After defining the type of general criterion, it is necessary to determine the value of function preference of action *a* in relation to action *b* for each criterion, and calculate the index of preferences (*IP*) of action *a* in relation to action *b*. Each pair of actions is in set *A*. The index preference is calculated in the following way:

$$IP(a,b) = \sum_{j}^{n} W_j P_j(a,b), \quad b\sum W_j = 1 \quad (5)$$

where W_j is the weight of criterion "*j*".

If all criteria have the same weight, that is if $W_j = 1/n$, so the index preference is:

$$IP(a,b) = (1/n) \cdot \sum_{j}^{n} P_j(a,b), \quad (6)$$

and which is determined by the following relation:

$$0 \leq P_j(a,b) \leq 1. \quad (7)$$

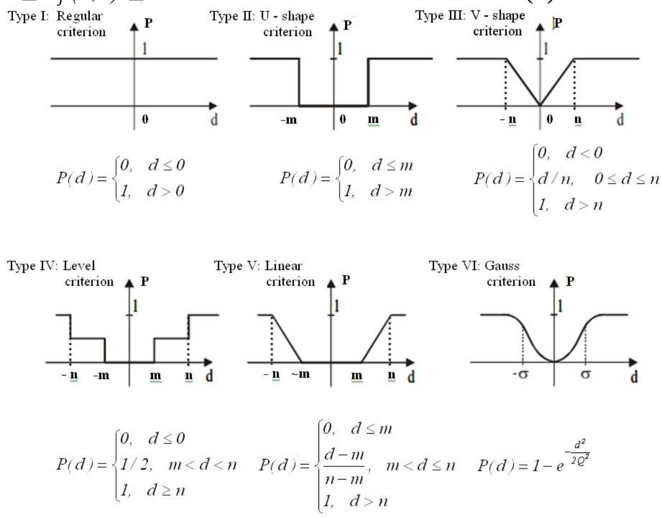

Fig. 3. Types of preference functions P (d) with parameters that illustrate them

After determining index preference *IP (a, b)*, it is finally possible to calculate alternative flaw index *T (a)*, the value of which represents the significance of the alternative. According to this index, the final decision about adequacy of one alternative from the set of alternatives is made. It is determined as:

$$T(a) = \frac{\sum_{x \in A} IP(a,x)}{i-1} \quad (8)$$

The selection of criteria to be used in the decision process needs to be done carefully so that the majority of chosen criteria define the problem at hand adequately and in accordance with decision maker's given requests. In this way, the influence of experience and subjective evaluation of decision maker during selection of generalized criteria is maximally reduced.

4.3. Mathematical model implementation

The essence of the problem is, using mathematical support, to find indexes *T (a)* of the countries that are situated on the BP. *T (a)* index evaluates logistic performances of a country's system. According to these indexes, it is possible to determine the level of logistic strength and stability for the countries of the BP. The country that has the strongest *T(a)* indexes represents the best location solution for LC. *T(a)* index solutions are obtained using PROMETHEE method. As the alternatives, the following *10* countries of the BP are considered ($A_i = 10$): Albany, Bosnia and Herzegovina, Bulgaria, Montenegro, Croatia, Greece, Macedonia, Romania, Slovenia and Serbia. Criteria and weight coefficients, on the basis of which the given alternatives are evaluated, are considered by *5* respondents who stand for very competent experts in logistics.

The study was performed in three leader logistic companies and two faculties. Companies' and faculties' experts evaluated criteria, and using mathematical method, final *T(a)* index was obtained. During evaluation of alternative (A_i), $C_j=20$ criteria have been used (fig. 4). The criteria are marked with indexes C_j and they include: safety (C_1), political stability (C_2), geographical position (C_3), inflation (C_4), the presence of trade barriers (C_5), road infrastructure (C_6), bank credit conditions (C_7), bribe and corruption (C_8), harbor infrastructure (C_9), the quality of complete infrastructure (C_{10}), the complexity of customs control (C_{11}), railway infrastructure (C_{12}), air traffic development (C_{13}), the number of local suppliers (C_{14}), fees and taxes (C_{15}), country salary and productivity (C_{16}), court effectiveness (C_{17}), anti-monopoly politics (C_{18}), local competition (C_{19}), and the development of supply chains (C_{20}).

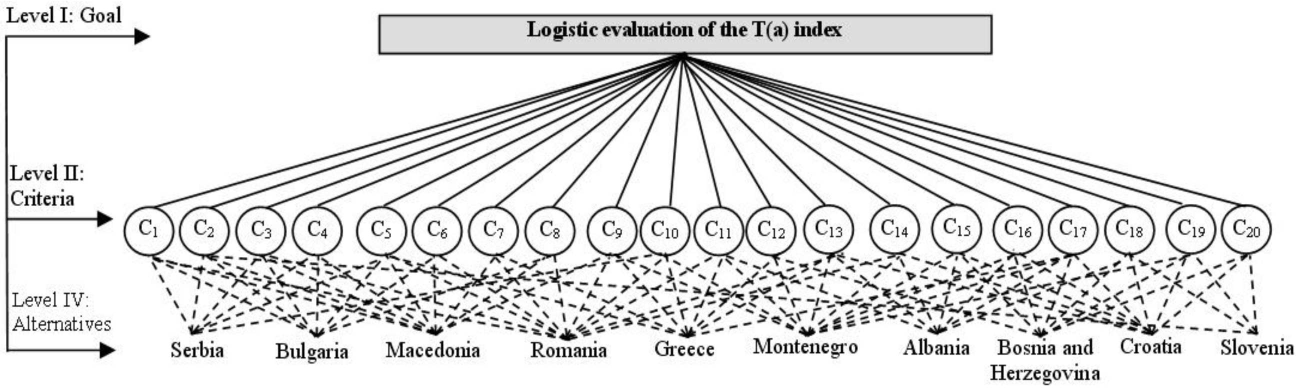

Fig. 4. Basic parameters in PROMETHEE II method (alternatives A_i and criteria C_j)

Such an approach reduces the mistake of subjective evaluation of the author considerably. The results of ranking and criteria evaluation are illustrated in table 2 by experts. The experts used scale (table 3) for qualifying qualitative values of criteria C_j [32]. After evaluating these criteria C_j, the experts also defined weights W_j for the criteria. Sum of all criteria weights equals 1. It may be concluded that the safety criterion is the most influential, because its influence is *15%* of the total influence of all criteria, while the rest of the criteria are weaker. Many criteria have equal influence, as it is the case with facility of getting a bank credit (C_7) and corruption (C_8).

Table 2. Evaluation of criteria C_j for each alternative-country A_i on the level of importance

Criteria	Serbia	Bulgaria	Maced.	Roman.	Greec	Monten.	Albania.	BIH	Croatia	Slovenia	Weights W_j
C_1	4	3.5	4	4	4	5	4.5	4	4.5	5	0.15
C_2	2	2	3	2	2	3.5	3	2	2	3	0.14
C_3	5	5	4	5	3	2	1	2	2	1	0.11
C_4	1	4	5	3	4	3	4	5	4	5	0.08
C_5	4.5	4	4.5	5	5	5	5	4	5	5	0.11
C_6	2.5	2	3	2	4	3	3.5	1.5	5	4.5	0.08
C_7	2.5	3	2	2.5	2.5	3.5	2.5	2	2.5	3	0.06
C_8	3.5	3.5	4.5	4.5	3.5	4	4	3.5	4	5	0.06
C_9	2.8	3.8	3.7	3	4	3.4	3.5	1.6	4	5.3	0.04
C_{10}	3	3	4	2.5	4.5	3	3.5	2	5	5	0.03
C_{11}	3.5	3.5	4.5	4	4	4.5	4	3.5	4	5	0.03
C_{12}	2	3	2.5	2.5	3	3	1.5	2	3.5	3	0.03
C_{13}	3	4	3	4	5	4.1	5	2.5	4.5	5	0.02
C_{14}	4.5	4.5	5	4.5	4.5	4.5	4	4	4.5	5	0.02
C_{15}	3	3	5	2	2	3	2	3	3	3	0.015
C_{16}	3.5	4	4	4.5	3	4	5	3	3.5	4	0.005
C_{17}	2.5	3	3	2.9	3	4	4	2	3	4	0.005
C_{18}	3	3.5	4	4	4	4	3.5	3	4	5	0.005
C_{19}	4	4.5	4.5	5	5	4	4	3.5	4	5	0.005
C_{20}	3	3	3.5	3	3.5	4	3	3	3	4.5	0.005

Table 3. Linear quantifications of qualitative attributes

1	2	3	4	5
Very low	Low	Medium	Strong	Very strong

Beside weight factors Wj, a decision maker has to be able to assign to each Cj criterion a corresponding preference function P(d) (fig.3). Beside the preference function, it is necessary to determine which function is minimized and which is maximized. In this work, the criteria belonging to the category of finances and the criteria having a negative influence on logistic performances (for e.g. inflation) of the system are minimized, while the criteria improving business conditions (for e.g. road infrastructure) are maximized. In table 2, all criteria functions are maximized, but it was satisfy previous statement by evaluation shown in table 3.

By final implementation of PROMETHEE method in the process of solving problems of multi-criteria deciding for
evaluating indexes of preferences IP (a,b) (3), the results of final index of alternative flaw T(a) (6) are obtained, and their values are illustrated in Table 4. Slovenia, on the basis of given criteria, took the first place on the rank list, while Bosnia and Herzegovina is the lowest ranked with T(a) = -0.527.

Table 4. Final BP countries' ranking on the basis of T(a) index

Alternative	Slove.	Monte.	Croat.	Maced.	Albania	Greec.	Roma.	Bulgar.	Serbia	BIH
Rang	1	2	3	4	5	6	7	8	9	10
T(a)	0.552	0.323	0.185	0.118	0.079	0.011	-0.115	-0.288	-0.338	-0.527

V.5. Results analysis

In order to analyze the results, special software for data processing, D-Sight [33], has been used. The platform, on which D-Sight software has been developing, is closely connected to PROMETHEE method. D-Sight program facilitates development of the model according to the PROMETHEE method through the following steps: setting alternatives, setting criteria, setting weight coefficients for criteria separately, setting alternatives' weights and their normalization, determining function of criteria and their maximization/minimization, and reading results. Similar solutions have been also offered by Tomic [34], unlike this paper, we use Greedy heuristic algorithm to support PROMETHEE method in order to obtain more accurate results. Graphic illustration of result it's illustrated in figure 5. All alternatives are presented with different colors, and for each of alternatives the value of criteria is obtained. The value of criteria estimates from 1 to -1, where 1 stands for the highest result and -1 for the lowest. For the purpose of easy results analysis (fig. 6), 3 alternatives are selected and mutually compared: Slovenia and Montenegro as the highest ranked and BIH as the lowest ranked alternative.

In fig. 6, advantages and disadvantages of Slovenia in relation to Montenegro and BIH are illustrated for each criterion. Reading the results obtained by PROMETHEE method of multi-criteria decisions supported by program D-Sight, it is graphically confirmed that Slovenia has the strongest T(a) index. Slovenia earned the highest T(a) index thanks to very good results for each criterion. By analyzing results, criteria which contributed to Slovenia having such a strong index are: less presence of bribe and corruption (C8) in relation to other alternatives (countries), better harbor infrastructure (C9), good customs control (C11) and anti-monopoly politics (C18), beside that Slovenia also has more developed supply chain (C20) in comparison to other alternatives. Montenegro, as the second ranked, has more developed political stability (C2), better geographical position (C3) and better conditions for bank crediting (C7) from Slovenia. However, beside all these reasons, according to total results, Slovenia offers better solution for LC location in comparison to Montenegro. On the other hand in Bosnia and Herzegovina, criteria that mostly affected negative T(a) index are: weak road infrastructure (C6), precisely, weakly developed total infrastructure (C10) and disability of port development has the greatest influence on all this (C9), beside this, air traffic development (C13), court effectiveness (C17) and local competition (C19) also earned the weakest results (-1).

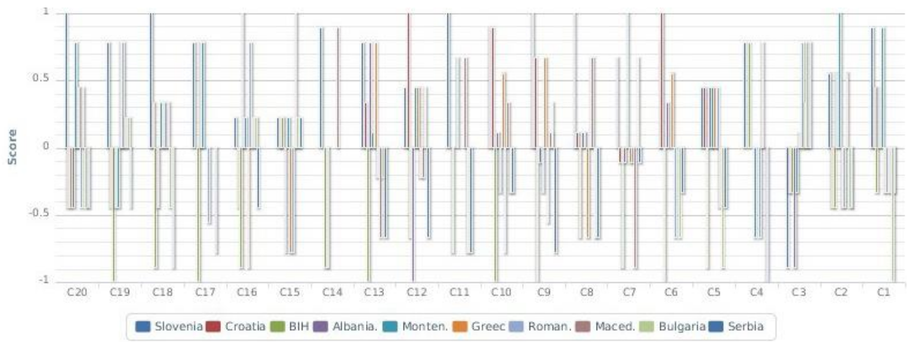

Fig. 5. Criteria results for each alternative

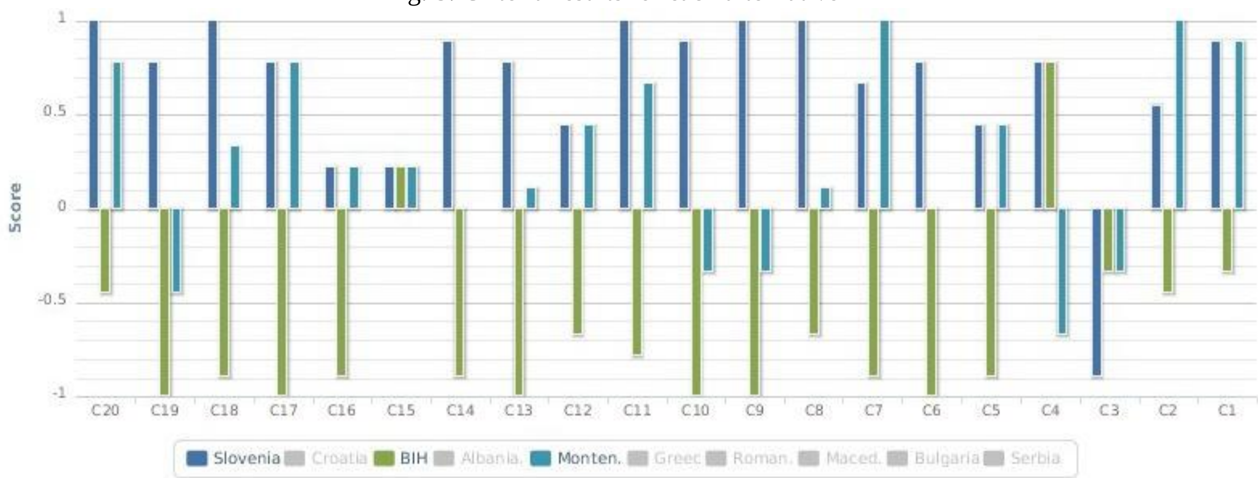

Fig. 6. Criteria results on the example of Slovenia, Montenegro and BIH alternative

VI. Conclusion

This research provides an analysis of potentials and obstacles in the process of BP integration in the Europe logistic system. The idea of this paper is to give the methodology of selecting and ranking suitable LC locations on the BP using the multi-modal method access. A special part of the research belongs to the Greedy heuristic algorithm and PROMETHEE method, and to their implementation during location problems solving. PROMETHEE method is ranked as one of the most famous and most frequently used methods of multi-criteria decisions. Theoretic basis of this method has been presented, and its application has been demonstrated by finding T(a) indexes of the BP countries. By using PROMETHEE method, T(a) indexes are obtained for ten countries of the BP on the basis of twenty criteria. The country that has the strongest T(a) indexes represents the best location solution for LC. According to these results, Slovenia emerged as a country which offers the most suitable logistic conditions, while the second and the third place belong to Montenegro and Croatia, respectively. Using D-Sight software, analytic solutions are qualitatively analyzed and verified.

Using these methods, alternatives are efficiently evaluated while subjective mistakes of decision makers are avoided. In this way, these methods have become a powerful tool for the decision maker, which provides a strong support in the process of solving complex location problems of multi-criteria decisions. Finally, using these methods in this research the aim has been reached, logistical comparison of the BP countries is done, and the most suitable LC location is recommended.

Further, this research not only explains how environmental performance influences LC, but also it is possibility of applying this model in other fields, such as decisions in supply chains, decision in management or decisions that may arise in everyday life. In making such decisions it is recommended that decision maker used this mathematical model to find the suitable solution.

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