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PROMETHEE METHOD IMPLEMENTATION WITH MULTI-CRITERIA DECISIONS*

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Abstract. *The Balkan Peninsula integration into the modern logistic flows of the European supply chains represents one of the basic infrastructural objectives of the countries in the region. In order to objectively analyze the level of logistic competition of Balkan Peninsula countries, the Promethee II mathematical method of multi-criteria evaluation is used in this paper. The primary aim of this research is to explain the role and significance of the multi-criteria method evaluation using a real example. Using Promethee II method, ten countries of the Balkan Peninsula are logistically evaluated and mutually compared. The logistic evaluation of the countries is performed according to 20 evaluation criteria forming the basis for supply chain logistic evaluation. The results, obtained by the multi-criteria evaluation using the presented method, gives the possibility of identification and evaluation of the most frequent logistic problems for each country separately. In this way, the method has proved to be a successful tool for the evaluation of the Balkan Peninsula countries' logistic competition.*

Key words: *Multi-criteria Decisions, Promethee II Method, Logistic Competition*

1 INTRODUCTION

Over the last few decades, new methods have been found and the methodology of decision-making process has been improving. Decision-making problems usually imply the selection of the best compromise solution. Besides the real criteria values by which a decision is made, the selection of the best solution also depends on the decision maker, that is, on his individual preferences [1]. In order to simplify the decision-making process, many mathematical methods have been suggested. The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) represents one of the most frequently used methods of multi-criteria decisions. Besides this method, other ones are also available. The Method of Analytical Hierarchical Processes (AHP) and the ELECTRE method have a significant place in the mathematical description of complex processes arising in

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the decision-making. All these methods have one basic task: to help the process of alternative evaluation.

The methods of multi-criteria decisions are possible to implement in solving technical, as well as logistic systems. In solving technical problems, these methods are widely implemented to the selection of the kind and type of heavy transport, construction and mining machines for certain areas of exploitation. Some examples are: selection of bucket-wheel excavator for surface mining, mechanization for container terminals, internal transport and warehouse equipment, etc.

In this paper, the PROMETHEE II method is used for the sake of logistic comparison of ten 10 countries, which represent alternative solutions (A_i) of the Balkan Peninsula (BP). According to 20 criteria (C_i) their mutual competition is evaluated. Similar research has been done by the World Bank, where the logistic competition of the world's countries is done on the basis of the Logistic Performances Index (LPI) [2]. In this research, though, only the BP countries are taken into consideration, while the number of criteria is significantly enlarged comparing to the criteria used by the World's Bank. As a result, new relevant indexes are obtained, which show more clearly which country of the BP is logistically developed. In this way, the BP, which in the history has been an icon for the connections between the eastern and western markets, can identify its position easily in relation to the global supply chains.

2 LITERATURE SURVEY

The decision-making, as a concept, is widely used, because it is present in everyday life. There are many definitions of decision-making process: according to H. Koontz and H.Weihrich [3] the decision is defined as choice of the most suitable alternative with respect to the predefined criteria, while T. Hunjak [4] defines it as collection of activities from the problem definition to the alternative selection. As with the decision definition, so with the process of decision-making: there are a few different levels (Fig. 1) [5]: identification and definition of problems, determining collection of alternative solutions (A_i), determining collection of criteria for alternative evaluation (C_j), alternative evaluation and, finally, alternative selection.

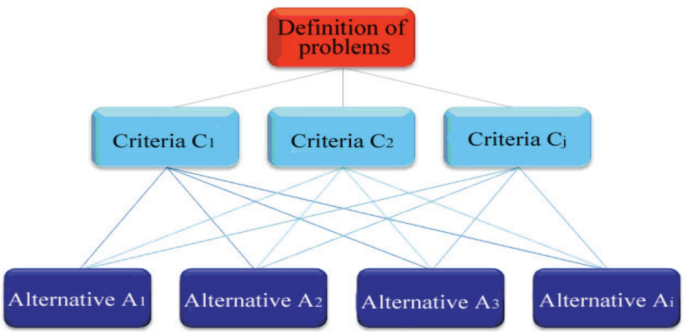

Fig. 1 Phases of decision making

PROMETHEE I and PROMETHEE II methods are developed by J. P. Brans and presented for the first time in 1982 at the conference "L'ingénièrie de la decision" organized at the University of Laval in Canada [6]. In the same year, several practical examples of application of the methods were presented by G. Davignon [7], and several years later, J.P. Brans and B. Mareschal developed PROMETHEE III and PROMETHEE IV methods [8, 9]. The same authors also suggested visual, interactive modulation GAIA, which represents a graphic interpretation of the PROMETHEE method, and in 1992 and 1995, they suggested two more modifications – PROMETHEE V and PROMETHEE VI [10, 11]. Many successful implementations of the PROMETHEE method to various fields are evident, and as such, these methods have found their place in banking, investments, medicine, chemistry, tourism, etc [12].

3 Mathematical model

The PROMETHEE method is based on mutual comparison of each alternative pair with respect to each of the selected criteria. In order to perform alternative ranking by the PROMETHEE method, it is necessary to define preference function $P\ (a,b)$ for alternatives a and b after defining the criteria. Alternatives a and b are evaluated according to the criteria functions. It is considered that alternative a is better than alternative b according to criterion f, if $f\ (a) > f\ (b)$. The 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 represent 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:

$$0 < P(a,b) > 1\ , \tag{1}$$

$$P(a,b) \neq P(b,a)\ . \tag{2}$$

Higher preference is defined by higher value from the given interval. This means that, for each criterion, the decision maker considers certain preference function [13]. In Fig. 2, 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. 2, besides criteria functions, the 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 $P(d) = 1/2$, it is possible to give any value $0 < P(d) < 1$.

In Fig. 2, 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:

$$IP(a,b)=\sum_{j}^{n} W_j P_j(a,b),\ b\sum W_j = 1\,, \tag{3}$$

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

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

$$IP(a,b)=(1/n)\cdot\sum_{j}^{n} P_j(a,b), \tag{4}$$

and which is determined by the following relation:

$$0 \le P_j\,(a,b) \le 1. \tag{5}$$

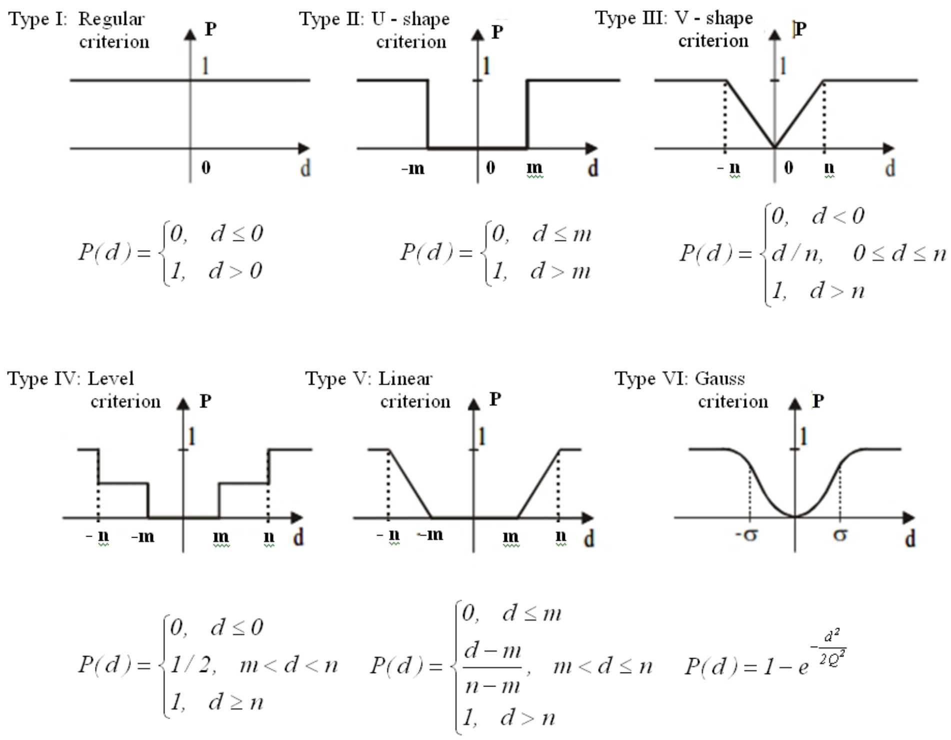

Fig. 2 Types of preference functions *P* (*d*) with parameters that illustrate them

After determining index preference *IP* (*a,b*), it is finally possible to calculate alternative flaw index *T* (*a*), whose value 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:

$$T(a) = \frac{\sum_{x \in A} IP(a,x)}{i-1}. \quad (6)$$

The selection of criteria to be used in the decision process needs to be done carefully so that the majority of the chosen criteria define the problem at hand adequately and in accordance with the decision maker's given requests [14]. In this way, the influence of experience and subjective evaluation of the decision maker during selection of generalized criteria is maximally reduced.

4 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 BP countries. $T(a)$ index solutions are obtained by means of the 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 regarded as 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. 3). 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}).

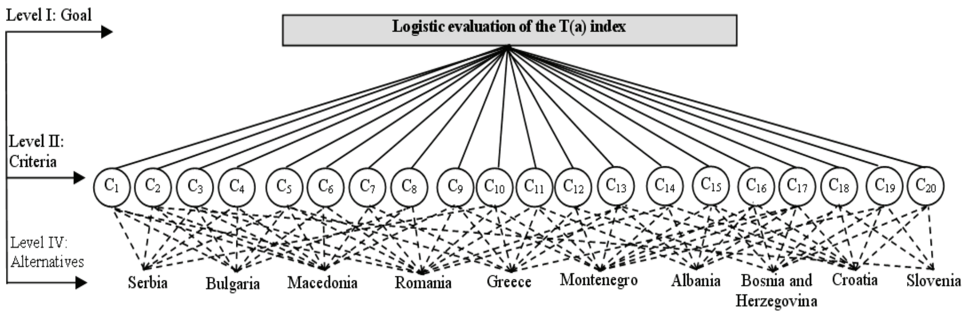

Fig. 3 Basic parameters in PROMETHEE II method (alternatives A_i and criteria C_j)

Such an approach reduces the mistake of subjective evaluation of the author considerably. The results of ranking and criteria evaluation are illustrated in Table 1 by experts. The experts used scale (Table 2) for qualifying qualitative values of criteria C_j [15]. After evaluating criteria C_j, the experts also defined weights W_j for the criteria. The 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 credit (C_7) and corruption (C_8).

Table 1 Evaluation of criteria C_j for each alternative-country A_i on the level of importance

Criteria	Serbia	Bulgar.	Mace.	Roma.	Greec.	Monte.	Alban.	B&H	Croat.	Slove.	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	3	2	2	4	3	3	3	4	2	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	0.02
C_{16}	3.5	4	4	4.5	3	4	5	3	3.5	4	0.01
C_{17}	2.5	3	3	2.9	3	4	4	2	3	4	0.01
C_{18}	3	3.5	4	4	4	4	3.5	3	4	5	0.01
C_{19}	4	4.5	4.5	5	5	4	4	3.5	4	5	0.01
C_{20}	3	3	3.5	3	3.5	4	3	3	3	4.5	0.01

Table 2 Linear quantifications of qualitative attributes

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

Besides weight factors W_j, the decision maker has to be able to assign to each C_j criterion a corresponding preference function $P(d)$ (Fig.2). Besides the preference function, it is necessary to determine which function is minimized and which is maximized. In this paper, the criteria belonging to the category of finances and the criteria having a negative influence on the system's logistic performances are minimized, while the criteria improving business conditions are maximized.

By final implementation of the PROMETHEE II method in the process of solving problems of multi-criteria decision-making 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 3. Croatia, 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) = -0.359*.

Table 3 Final BP countries' ranking on the basis of T(a) index

Alternative	Croat.	Monte.	Slove.	Greec.	Bulgar.	Serbia	Albania	Roma.	Maced.	B&H
Rang	1	2	3	4	5	6	7	8	9	10
T(a)	0.217	0.159	0.090	0.050	0.045	0.040	0.008	-0.026	-0.225	- 0.359

5 Results analysis

In order to analyze the results, special software for data processing, D-Sight [16], has been used. The platform, on which D-Sight software has been developing, is closely connected to the 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 Cvetkovic[17] and Prvulovic [18].

Graphic illustration of result processing is obtained by using Global Visual Analysis tools (GVA), and it is illustrated in Fig. 4. Point *P* denotes an approximate value of all criteria weights and visually illustrates the optimal point, which the alternatives tend to achieve. Reading the results obtained by the PROMETHEE method of multi-criteria decisions supported by program D-Sight, it is graphically confirmed that Croatia has the strongest *T(a)* index. By analyzing results, criteria which contributed to Croatia's having such a strong index are: less presence of trade barriers in relation to other alternatives (countries), better road infrastructure and good safety. In Bosnia and Herzegovina, criteria that mostly affected negative *T(a)* index are: political instability, ineffectiveness of the legal system and difficulties in getting a bank credit.

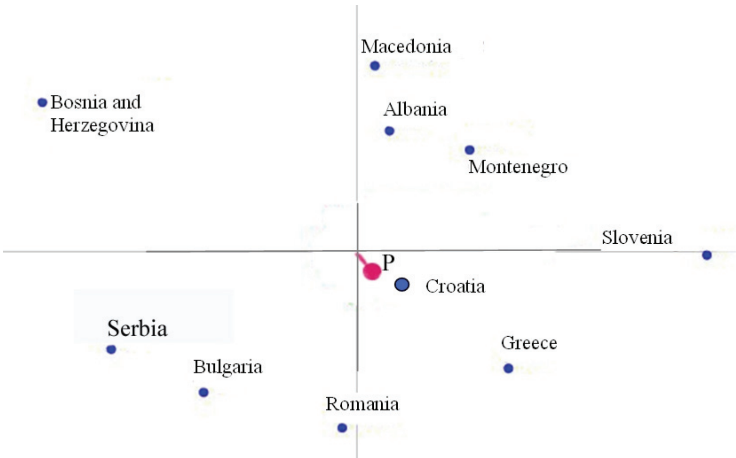

Fig. 4 Obtained alternative solutions by using D-Sight software

Using D-Sight software, comparison of the best Croatia's alternative with Serbia has been done. In Fig. 5, advantages and disadvantages of Serbia in relation to Croatia are illustrated for each criterion. One may notice that Serbia's safety criterion has weight of -0.78, while Croatia's has 0.33 in relation to ideal baseline. It means that Serbia, on the basis of this criterion, is much less competitive than Croatia. In this way, weight coefficients of the rest of the criteria are also compared.

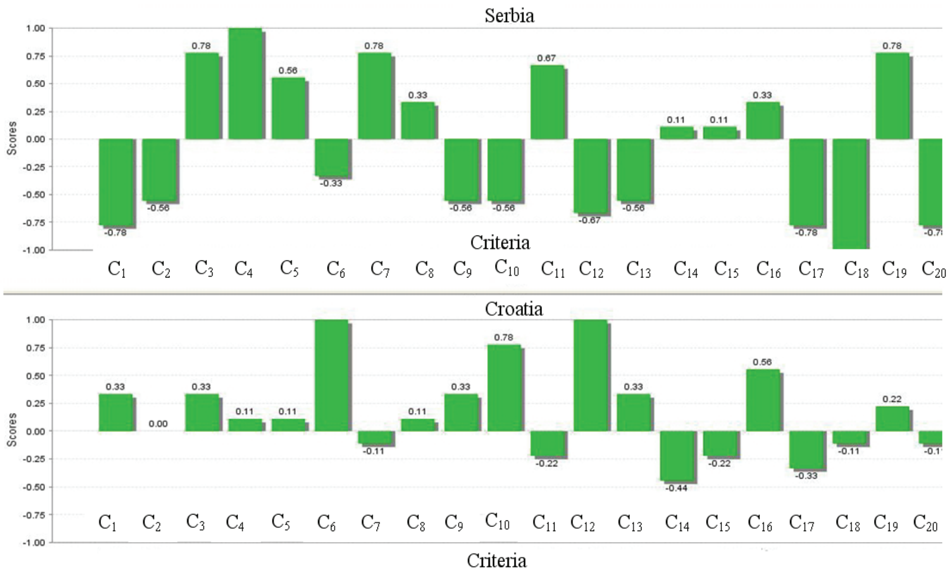

Fig. 5 Comparison of logistic competence of Serbia and Croatia

6 CONCLUSION

The aim of the research in this paper is to obtain *T(a)* indexes of the BP countries by using multi-criteria analysis. In this paper, the PROMETHEE method is used, as well as a mathematical tool in order to obtain $T(a)$ indexes. The 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 the PROMETHEE method, $T(a)$ indexes are obtained for ten countries of the BP on the basis of twenty criteria. According to these results, Croatia emerged as a country which offers the most suitable logistic conditions, while the second and the third place belong to Slovenia and Montenegro, respectively. According to $T(a)$ index, it is possible to determine the level of logistic competition in percentage in relation to other alternatives. Using D-Sight software, analytic solutions are qualitatively analyzed and verified.

Besides its quality, the success of the PROMETHEE method implementation in the process of decision-making greatly depends on possibilities and experience of the decision maker since he has to be able to prove the significance of each criterion and define it on an interval scale. If the previous conditions are fulfilled, the PROMETHEE method becomes a powerful tool for the decision maker, which provides a strong support in the process of solving complex problems of multi-criteria decisions.

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PRIMENA PROMETHEE METODE KOD VIŠEKRITERIJUMSKOG ODLUČIVANJA

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Integracija Balkankog Poluostrva u savremene logističke tokove Evropskih lanaca snabdevanja predstavlja jedan od osnovnih infrastrukturnih ciljeva zemalja koje se nalaze na ovim prostorima. Kako bi objektivno analizirali koliko je koja zemlja Balkanskog Poluostrva logistički konkurentna u odnosu na svoje susede u ovom radu je korišćen matematički metod višekriterijumskog ocenjivanja Promethee II. Osnovni cilj istraživanja sprovedenog u ovom radu je da se na realnom primeru objasni uloga i značaj metoda višekriterijumskog ocenjivanja. Pomoću Promethee II metode deset zemalja, koje se nalaze na Balkanskom Poluostrvu, logistički je ocenjeno i medjusobno uporedjeno. Logističko ocenjivanje zemalja izvršeno je na osnovu ocene 20 kriterijuma koji čine osnovu logističkog vrednovanja svakog lanaca snabdevanja. Rezultati dobijeni višekriterijumskim ocenjivanjem uz upotrebu prezentovane metode, upućuju na mogućnost identifikacije i vrednovanja najučestalijih logističkih problema svake zemlje pojedinačno. Na ovaj način metoda se pokazala kao uspešan alat prilikom ocenjivanja logističke konkurentnosti zemalja Balkanskog Poluostrva).

Ključne reči: *višekriterijumsko odlučivanje, Prometej II metoda, logistička konkurentnost*