Identification of Appropriate Methods for Allocation Tasks of Logistics Objects in a Certain Area

Identifikacija odgovarajućih metoda za zadatke za raspodjelu logističkih objekata u pojedinim područjima

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Summary

This paper aims at identification of appropriate multi-criteria analysis methods for allocation tasks of logistics objects in a certain area. The given type of tasks (allocation tasks) can be seen as a decision problem; for this type of task the multi-criteria analysis methods is used. The first part of this paper presents a brief introduction to the given issue. The second part of the paper includes characteristics of the general procedure for multi-criteria evaluation of the variants. The third part includes an overview of utilized methods for determining criteria weightings and methods of selection of the most suitable variant. The forth part presents the summary of the described methods, identification of appropriate methods for a given type of task and a model example for determination of criteria weightings.

KEY WORDS

allocations tasks
logistics objects
multi-criteria analysis
Saaty's pair wise comparison method
weighted sum analysis

Sažetak

U ovom radu nastoji se identificirati odgovarajuće višekriterijske metode analize zadataka za raspodjelu logističkih objekata u pojedinim područjima. Dati primjeri zadataka (zadataka za raspodjelu) mogu se promatrati kao pitanje odluke; za ovaj tip zadatka koristi se višekriterijska metoda analize. U prvom dijelu rada dat je kratki uvod o predmetu rada. Drugi dio rada uključuje karakteristike opće procedure za višekriterijsku procjenu varijanti. Treći dio uključuje pregled upotrebljenih metoda za određivanje kriterija ponderiranja i metoda selekcije najpovoljnije varijante. U četvrtom dijelu dat je sažetak opisanih metoda, identifikacija odgovarajućih metoda za određene zadatke i primjer modela za određivanje kriterija ponderiranja.

KLJUČNE RIJEČI

zadatci za raspodjelu
logistički objekti
višekriterijska analiza
Saaty metoda usporedbe u parovima
analiza ponderirane sume

INTRODUCTION / *Uvod*

The decision means to choose in a given situation one option from a list of potentially viable variants against a large number of criteria. Next to the list of criteria indirectly forming the objective of the decision analysis it is necessary to have a list of variants from which to choose from. Cases where a clearly defined list of potential variants is available are more or less the exception than the rule [1], [2].

If there is a list of criteria and a list of decision variants, it is necessary to consider in detail what form the final decision should take. If we insist that it is really necessary to choose only one optimal variant, we need to accept that in typical cases we want to get something out of unreliable and insufficient information that is almost certainly not included. For a task formulated in this way there is a requirement to arrange the decision variants in order according to how close they are to the most optimal variant [2].

GENERAL PROCEDURE FOR MULTI-CRITERIA EVALUATION OF VARIANTS / *Opća procedura za višekriterijsku procjenu varijanti*

In order to standardize, define and select methods of evaluation for multi-criteria evaluation of variants which support decision making, it is necessary to know: what is to be decided, what goals are to be met (what objectives are to be achieved and under what conditions), aspects of what is to be decided (what aspects the decision-making process must comply with), the time line for the outcome of the decision making process [3].

The general procedure for the multi-criteria evaluation of variants involves six relatively distinct steps [4]:

The general procedure for multi-criteria evaluation of variants as an integral part of a multi-criteria decision-making process of

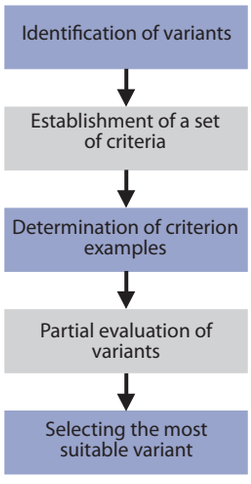

Figure1. Sequence of steps for multi-criteria analysis
Slika 1. Kronološki prikaz koraka u višekriterijskoj analizi
Source: authors

variants assumes that there are at least two possible variants as solutions for the issue [5].

OVERVIEW OF EXISTING METHODS FOR DETERMINING CRITERIA WEIGHTINGS AND METHODS OF SELECTION OF THE MOST SUITABLE VARIANT / *Pregled postojećih metoda za određivanje kriterija ponderiranja i metoda odabira najpovoljnije varijante*

DETERMINATION OF CRITERIA WEIGHTINGS / *Određivanje kriterija ponderiranja*

This step of the general procedure of multi-criteria assessment of variants is closely related to the completeness of a set of criteria reflecting the essential characteristics of the variant. In cases where the set of criteria is relatively complete it is necessary to consider the individual gravity (importance) of each criterion during evaluation, and the result of its importance, or lack thereof, for this purpose. Criterion weightings may be established either before performing a partial evaluation of the variants, or subsequently for correcting the obtained results [6].

When using differentiated weight criteria, the evaluation results are dependent on the choice of these weights for which applies: if with a small number of criteria we get a high weighting for a certain criterion then the evaluation results tend to arrange the evaluated variants according to this criterion; whereas a large number of criteria leads to the fragmentation of weightings and even if the weights of individual criteria do not differ much they still allow differentiation [6].

METHODS FOR DETERMINING CRITERIA WEIGHTINGS / *Metode određivanja kriterija ponderiranja*

Determining criteria weightings is usually a crucial step in the analysis of the model of multi-criteria analysis of variants. The information obtained from any of the following procedures is used to determine the preferential relations between variants depending on the objectives of the entire analysis. Methods for the determination of weights can be divided according to the information we have on the preference of criteria [5], [6]:

a.) the user has **no information**,
b.) methods working with **ordinal information,**
c.) methods for determining the weightings of criteria from **cardinal information**.

Table 1. Methods for determination of criteria weightings
Tablica 1. Metode određivanja kriterija ponderiranja

Determination of criteria weightings		
Information about preferences between criteria		
None	Ordinal	Cardinal
Method of equal weights	Method of ranking	Scoring method
Entropy method	Fuller method	Saaty method

Source: [5], [6]

Method of equal weights - The same weight is assigned to all criteria.

Appropriateness of method	
☐	Using the method for this type of tasks is inappropriate because it does not allow for the specification of preferences among criteria.

Entropy method - The method uses the assumption that the criterion is not very important if the values of all variants in the criteria matrix according to this criterion are similar; and vice versa the criterion is the more important the more the values of the variants differ. Therefore, this method can be used to determine the weightings of the criteria.

Appropriateness of method	
☐	Using the method for this type of tasks is inappropriate. To a degree it allows for the determination of preference among the criteria, however this preference is dependent on the sizes of values in the criteria matrix and does not reflect the true significance of each criterion.

Method of ranking - The method of ranking is primarily used in cases where their importance is evaluated by several experts. Each of the experts arranges the criteria from the most important to the least important. The most important criterion are evaluated by points which correspond to the number of criteria; the second most important criterion will get one point less and so on until the least important criterion only gets 1 point. In case of equal importance of the criteria, these criteria get points according to the average order.

The weight of each criterion is determined by counting the points given by all experts (for a given criterion); this sum is then divided by the total number of points which the experts shared between all the criteria. This ensures that the sum of weights of all the criteria is equal to 1.

Appropriateness of method	
☐	Using the method for this type of tasks is inappropriate. The disadvantage is that the resulting value of the weight is derived from the order and that preference is not given sufficient significance.

Method of comparison in Fuller triangle - If ordinal information only expresses the relationship between each pair of evaluated criteria, it is possible to use the method of pair wise comparisons. In cases where a user reviews criterion *j* as being more important than *l* it also stands that criterion *l* is considered to belles important than criterion *j*, it is sufficient to perform a number of comparisons (*n* is the number of criteria). This comparison is usually done using the so-called Fuller triangle. In each pair of elements, the element that is considered to be more important is circled.

Appropriateness of method	
☐☐	Using the method for this type of tasks is less suitable. The downside, as with the previous method is the lack of significance given to preference.

Scoring method - The importance of each criterion according to this method is expressed by a certain number of points within the defined scoring scale. Decimal numbers can also be used and more than one criterion may be assigned the same point value. This method is also used for calculating the weights in a similar way to the method of ranking where the criteria are evaluated by several experts. Each expert evaluates each criterion with a certain number of points; the more important the criterion is the more points it gets (using a scale from 0 to 10 one criterion may get 0 points from an expert who regards it as insignificant and 10 points from an expert who regards it as absolutely important). The calculation of the weights is done in the same way as in the method of ranking.

Appropriateness of method	
☐☐	Using the method for this type of tasks is less suitable. This method appears to be the most appropriate of all those presented so far. Scoring of the importance of each criterion by a number of experts adds relevance.

Saaty pair wise comparison method - This is a method of quantitative pair wise comparison of criteria. For the evaluation of paired comparison of criteria, a 9 point scale is used. It is also possible to use intermediate values (2, 4, 6, 8) [7]:

1 - equal criteria *i* and *j*,
3 - slightly preferred criterion *i* above j,
5 - strongly preferred criterion *i* above j,
7 –very strongly preferred criterion *i* above j,
9 - absolutely preferred criterion *i* above j.

The researcher compares each pair of criteria and enters the sizes of preferences of *i*-thin relation to the *j*- th criterion in the Saaty matrix. In case *j*- th criterion is preferred above that oft he *i*- th criterion, inverse values are entered into the Saaty matrix (*sij*=1/3 for low preference, *sij* =1/5 for strong preference, etc.) [7].

This already indicates the basic characteristics of the Saaty matrix. Saaty designed several numerically very simple ways by which the weights *vj*- can be estimated. The most commonly used method of calculating weights is the normalized geometric mean of a line in a Saaty matrix, the procedure is sometimes called "logarithmic least squares method". The Saaty method can be used not only to determine the preferences between criteria, but also between variants by analyzing the original task, which is overwritten as a hierarchical order [7], [8].

Appropriateness of method	
☐☐☐	Using the method for this type of tasks is suitable. It allows for the determination of preferences not only among the criteria but also between variants.

On the basis of the above analysis of methods for determining the weightings of criteria, we decided to use the Saaty pair wise comparison method because it appears to be the most appropriate of all the described methods.

CHOOSING THE MOST SUITABLE VARIANT / *Odabir najpovoljnije varijante*

There are a number of methods that are used for solving multi-criteria analysis. The simple ones do not take into account the weight of each criterion and therefore are not appropriate for this paper because in the group of criteria which influence the logistics object, significant differences in the importance of criteria exist. The aim of this part of this paper is to outline the importance and use of several methods of multi-criteria analysis. A detailed description of other methods can be found in literature dealing with this issue [4].

METHODS OF SELECTING THE MOST SUITABLE VARIANT / *Metode odabira najpovoljnije varijante*

Methods for the selection of avariant are divided according to what information about the preference among the criteria they require for their work [4], [5]:

a.) methods **notrequiring information** about preference of criteria,
b.) methods **requiring aspiration** level of criteria,
c.) methods using **ordinal information** on the criteria,
d.) methods requiring **cardinal information** about the criteria,

- ✓ maximizing the benefits
- ✓ minimizing the distance from the ideal variant
- ✓ preferential relationship.

Simple method of scoring - This method can be used if the model is specified using only the preference of variantsaccording to individual criteria and criteria preferences are not known.

Appropriateness of method	
☐	Using the method for this type of tasks is inappropriate.

Simple method of ranking - The method can also be used if the model is specified using only the preference of variants according to individual criteria and criteria preferences are not known.

Appropriateness of method	
☐	Using the method for this type of tasks is inappropriate.

Lexicographical method - The lexicographical method is based on the principle that the most important criterion has the greatest influence on the choice of a variant. Only in cases where several variants are rated the same is the next most important criterion taken into account. If an alternative variant

is not selected on the basis of this second criterion, the third most important variant is taken into account, and so on. The algorithm stops at the moment when only one variant is selected or when all criteria taken into account have been considered. The alternative variants are then all those that remained equally evaluated after the last criterion.

Appropriateness of method	
☐	Using this method for this type of tasks is inappropriate because it does not take into account values obtained by other criteria.

Permutation method - With this method it is important to know the order of importance of individual criteria. Further, it is important to realize that the number of variant permutations *m* is *m!*, which is a major drawback of this method. For this method it is necessary to know either the weights of individual criterion or at least the order of their importance.

Appropriateness of method	
☐	Using this method for this type of tasks is inappropriate.

ORESTE method - The method requires as input only ordinal information on criteria and variants. The investigator is required to complete quasi-ordering of criteria and to complete quasi-ordering of variants according to individual criteria i.e. indifference of criteria and variants is permitted. First, the distance of each variant according to each criterion from the fictional start is determined (order numbers of the fictional variant and fictional criterion are 0). On the basis of this calculated distance, the variants are arranged according to certain rules.

Appropriateness of method	
☐	Using this method for this type of tasks is inappropriate.

TOPSIS method - The TOPSIS method is one of the methods where the evaluation of options is performed by comparison with ideal variants. To express the distance between variants, different units are used. The TOPSIS method is based on the classical Euclidean metric space.

Appropriateness of method	
☐☐	Using this method for this type of tasks is less suitable.

Weighted Sum Analysis – WSA - The weighted sum method requires cardinal information, criteria matrix *Y* and a vector of criteria weightings *v*. It constructs the overall rating for each variant and so it can be used for finding one of the most appropriate variants as well as for arranging variants on a scale from the best to the worst. With this method we work with the weights of individual criterion, which are either entered or estimated appropriately (see previous scoring method for determining criteria weightings). Thus we get the weightings'=$(v_1, v_2, ..., v_k)$ for *k* of maximization criteria.

The method of weighted sum then maximizes the weighted sum i.e., $\sum_{j=1}^{k} v_j r_{ij}$ Hence we calculate the value of the weighted sum for each variant and as a compromise variant select the one with the highest weighted sum.

Appropriateness of method	
☐☐☐	Using the method for this type of tasks is appropriate because it constructs the overall rating for each variant.

AHP method - This method provides a framework for making effective decisions in complex decision-making situations, helping to simplify and accelerate the natural process of decision making. AHP is a method of decomposition of a complex unstructured situation into simpler components, thereby creating a hierarchical system for a problem.

At each level of the hierarchical structure the Saaty method of quantitative pair wise comparison is used. Using subjective ratings of pair wise comparison this method then assigns quantitative characteristics to each component indicating their importance. Synthesis of these evaluations then determines the component with the highest priority, which the investigator focuses on in order to obtain a solution to the decision problem.

The arrangement of the individual levels of hierarchical structure corresponds with the arrangement from general to specific. The more general the elements in relation to the given decision problem are, the higher they are in the hierarchy associated with the problem and vice versa.

Appropriateness of method	
☐☐	Using the method for this type of tasks is less suitable

Ardolana method - The Ardolana method is one of the heuristic methods, which is used to find the optimal placement for the deployment of objects in an area according to certain criteria. Calculations for the optimal allocation of objects are carried out by analyzing all the criteria that are to some extent able to influence the choice of allocation.

Appropriateness of method	
☐☐	Using the method for this type of tasks is less suitable

SUMMARY OF THE DESCRIBED METHODS AND AN IDENTIFICATION OF APPROPRIATE METHODS / *Sažetak opisanih metoda i identifikacija odgovarajućih metoda*

The selection of the appropriate method depends on the point of view of the investigator interested in the subject. Operational analysis methods from the field of graph theory deal with classical solutions for the allocation tasks. Most of the tasks from a real environment are too complex in terms of calculations for the application of these methods. Finding solutions for these tasks cannot be done without the use of a computer or even specialized software. [4].

Proposing the placement of logistics object can be viewed as a decision problem in which the final decision is influenced by a group of external factors. For the purpose of solving decision making problems the methods of multi-criteria analysis are used and these methods can therefore be used in deciding the location of logistics objects. There are many different methods of multi-criteria analysis which can help in the allocation of

these objects. In practice, however, many methods cannot be used because they do not allow for the processing of all the intricacies related to this issue.

Many methods cannot be applied to the multi-criteria function in our case. Another significant problem area for the application of certain methods is that we do not know the details of the customers and users of logistics objects, which we could have analyzed. On this basis it was decided to use the weighted sum method - WSA, which appears to be relatively easy to handle and easy to apply to the complex and difficult task of allocating logistics objects.

In its calculation the Weighted Sum Analysis method uses criteria with set weights. Again, there are several methods to determine the criteria weights. For the purposes of this type of tasks the Saaty pair wise comparison method was chosen. A number of criteria have lesser or greater influence on the decision of placing logistics objects. It was therefore necessary to choose such a method which allows human judgment to determine the relationship significance (preference) between two criteria being compared. Furthermore, the Saaty method allows for the detailed division of these preferences [4], [6].

MODEL EXAMPLE FOR THE DETERMINATION OF CRITERIA WEIGHTINGS / *Primjer modela za određivanje kriterija ponderiranja*

The individual criterion weights represent the importance of a given criterion for the selection of a variant using multi-criteria analysis. The higher the criterion weight is, the greater the impact on the decision of the resulting variant [4], [6].

As mentioned above, it is appropriate to determine the criteria weightings with the use of Saaty pair wise comparison method. First of all it is necessary to establish a set of criteria which influence the process of decision making in terms of allocation tasks (stage two of the process of multi-criteria analysis). After determining the objectives of the analysis of available knowledge, relevant to this article, 10 criteria primarily from socio-economic areas were defined. For clarity, the criteria (factors) are summarized in the following table (Table 2).

The next step of the Saaty method is to determine the relationship between each pair of criteria when the level of significance (preference) is determined in a spot range between 1-9. This is determined as follows [7], [9]:

To ensure the greatest possible objectivity in the allocation task for the allocation of logistics objects, five members of the research team (a team was formed for the purpose of solving the tasks in the post) were asked to determine preferences between individual criteria. Each of the five members of the team set a level of significance for each pair of criteria.

For each element of the matrix a sum of the sub-matrices of all members of the team was established and then the average was calculated.

Elements of the Saaty method were used for further calculations. The values obtained for the individual criterion in the intermediate calculations and the final values of the vector of weights of individual criterion are given in Table 4.

Table 2. Overview of criteria related to the solution of the problem of allocating logistics objects

Tablica 2. Pregled kriterija koji se odnose na rješenje problema raspoređivanja logističkih objekata

Criteria	Acronym (designation)
GDP per capita (PPS)	GDP
Average GDP growth over 5 years	GDPGR
Value of direct foreign investment (EUR thousands)	FDI
Amount of transported goods via public roads (thousands tonnes)	TGR
Number of large companies (> 250 employees)	NBE
Number of small and medium size companies (< 250 employees)	NSME
Population size	NP
Average gross monthly wage (EUR)	AGW
State of road network (km)	RN
Regional connections with network of railway lines AGTC	AGTC

Source: authors

Table 3. Resulting Saaty matrix

Tablica 3. Dobivena Saaty matrica

	Criterion	GDP	GDPGR	FDI	TGR	NBE	NSME	NP	AGW	RN	AGTC
1.	GDP (PPS)	1,00	2,00	3,00	0,33	2,00	1,00	1,00	0,50	0,33	0,50
2.	GDPGR	0,50	1,00	2,00	0,20	1,00	0,50	0,50	0,25	0,20	0,25
3.	FDI (EUR 000)	0,33	0,50	1,00	0,17	1,00	0,33	0,50	0,20	0,14	0,20
4.	TGR (tons 000)	3,00	5,00	6,00	1,00	5,00	2,00	3,00	2,00	1,00	2,00
5.	NBE	0,50	1,00	1,00	0,20	1,00	0,50	0,50	0,25	0,20	0,25
6.	NSME	1,00	2,00	3,00	0,50	2,00	1,00	1,00	0,50	0,50	0,50
7.	NP	1,00	2,00	2,00	0,33	2,00	1,00	1,00	0,50	0,33	0,50
8.	AGW (EUR)	2,00	4,00	5,00	0,50	4,00	2,00	2,00	1,00	0,50	1,00
9.	RN (km)	3,00	5,00	7,00	1,00	5,00	2,00	3,00	2,00	1,00	2,00
10.	AGTC	2,00	4,00	5,00	0,50	4,00	2,00	2,00	1,00	0,50	1,00

Source: authors

Table 4. Values obtained using the Saaty method

Tablica 4. Vrijednosti dobivene upotrebom Saaty metode

	Criterion	Sum of elements	Tenth square root of sum	Resulting weight of criterion
1.	GDP (PPS)	0,326700	0,894159	0,07198
2.	GDPGR	0,000625	0,478176	0,03850
3.	FDI (EUR 000)	0,000026	0,347934	0,02801
4.	TGR (tons 000)	10800,000000	2,531293	0,20378
5.	NBE	0,000313	0,446226	0,03593
6.	NSME	0,750000	0,971642	0,07823
7.	NP	0,217800	0,858629	0,06913
8.	AGW (EUR)	160,000000	1,661162	0,13374
9.	RN (km)	12600,000000	2,570615	0,20696
10.	AGTC	160,000000	1,661162	0,13374
				∑= 1,00000

Source: authors

CONCLUSION / *Zaključak*

The Saaty method appears to be appropriate. Inputs for the calculation were determined in the research team, and each member of the team could evaluate the relationship between the criteria using a nine-point scale. From this overview of setting criteria weightings by using the Saaty pair wise comparison method it is clear that the highest priority is assigned to transport infrastructure and also to transport characteristics of the region, which are represented by density of the road network and number of higher category AGTC lines passing through a given region, as well as the amount of goods transported by road transport.

The least important criteria are the number of large state enterprises and the level of direct foreign investment in the region. Large enterprises are partly assumed to have sufficient funds to build and manage their own logistics sites and therefore they will not be the target customers of the large logistics objects. As for direct foreign investment, it does not necessarily produce the desired effects by increasing the level of employment; they serve only as an indirect indicator of the financial performance of the given region [10].

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