Choosing the Suitable Method for Multimodal Logistics Object Location in the Slovak Republic and Setting up the Criteria Matrix

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Abstract This paper deals with the choosing of a suitable method for multimodal logistics object location in the Slovak Republic. The paper also describes several methods concerning the multimodal logistics object location in particular area, determines the crucial method related to this issue and presents setting up the criteria matrix for the needs of this object location in the Slovak Republic.

Keywords Multimodal logistics object, location, criteria matrix, method, variant, criterion

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1. Introduction

Choosing the appropriate area for multimodal logistics object location can be considered a decision problem.

The decision means in a given situation choosing 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. Cases where a clearly defined list of potential variants is available are more the exception than the rule. This list can be explicitly specified as the sum of a finite number of options, or specify the conditions that are considered acceptable and with which the decision options must comply.

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 create the order of variants.

2. Overview of Several Methods for Multimodal Logistics Object Location in Particular Area

Methods for the selection of a variant (variant for multimodal logistics object location) are divided depending on what information about the preference among the criteria is required [1-3]:

1. Methods not requiring information about criteria preference.

Methods that do not require information about the preference between criteria are very simple and in their plain form are rarely used.

2. Methods requiring aspiration level of criteria.

For methods that are based on work with aspiration information on preferences between criteria, it is characteristic that they do not try to transform the information of a user into a weight vector. Information about the importance of the criteria is expressed as the aspiration level of the criteria. These methods are useful in cases where aspiration values of criteria are known and cardinal evaluation of the variants according to individual criteria can be used.

3. Methods using ordinal information about the criteria.

Methods working with ordinal information about the criteria or variants require a specification of the order of criteria importance and the order of variants according to indi-

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vidual criteria. Some methods are very simple and the results are more or less indicative, others are quite complicated and provide a comprehensive view of the problem.

4. Methods requiring cardinal information about the criteria.

There are several methods that require cardinal information about the criteria in terms of weights and about the variants in the form of a criteria matrix with cardinal values. In this area there are three basic approaches to the evaluation of variants, according to:

- Maximizing the benefits,
- Minimizing the distance from the ideal variant,
- Preferential relationship.

2.1. Simple Method of Scoring

This method can be used if the model is specified using only the preference of variants according to individual criteria and criteria preferences are not known [1-3].

Appropriateness of method - Using the method in this paper is inappropriate.

2.2. 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 [1-3].

Appropriateness of method - Using the method in this paper is inappropriate.

2.3. Lexicographical Method

The lexicographical method is based on the principle that the most important criterion has the greatest influence on the choice of an multimodal logistics object location 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 [1-3].

Appropriateness of method - Using this method in this paper is inappropriate because it does not take into account values obtained by other criteria.

2.4. 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 [1-3].

Appropriateness of method - Using this method in this paper is inappropriate.

2.5. 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 [1-3].

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 the method in this paper is inappropriate.

2.6. 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 [1-3].

Appropriateness of method - Using this method in this paper is less suitable.

2.7. 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 [1-3].

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 $v=(v_1,v_2,...,v_k)$ for k of maximization criteria [1-3].

The method of weighted sum then maximizes the weighted sum, i.e.:

$$\sum_{j=1}^{k} v_j r_{ij}. \qquad (1)$$

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 in this paper is appropriate because it constructs the overall rating for each variant.

2.8. 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 [1-3].

At each level of the hierarchical structure the Saaty method of quantitative pairwise comparison is used. Using subjective ratings of pairwise 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 [1-3].

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 [1-3].

Appropriateness of method - Using the method in this paper is less suitable.

2.8. 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 [1-3].

Appropriateness of method - Using the method in this paper is less suitable.

3. Choosing the Crucial Method

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. [1].

There are many different methods which can help in the multimodal logistics object location issue (for example, methods of multi-criteria analysis). In practice, however, many methods cannot be used because they do not allow for the processing of all the intricacies intended in this article.

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 multimodal logistics object, which we could have analyzed [1-3].

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 multimodal logistics object location.

4. Setting up the Criteria Matrix for the Needs of Multimodal Logistics Object Location in the Slovak Republic

In the theory of Multiple Criteria Decision Making we work with a general number of criteria *k* and with a general number of *p*. The value achieved by variant *i* or *j-th* criterion is labelled as y_{ij} and is called the criterion value. The next step is to arrange these values into a matrix which we call the criteria matrix. The rows of the criteria matrix are formed by the individual variants. The columns of the criteria matrix correspond with the individual criteria [1].

The criteria matrix, therefore, has the following form (*Figure 1*):

$$\begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1k} \\ y_{21} & y_{22} & \cdots & y_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ y_{p1} & y_{p2} & \cdots & y_{pk} \end{pmatrix}$$

Figure 1. The general form of the criteria matrix

Source: [1]

4.1. Identification of variants

In stage one it is necessary to identify a set of variants from which the final solution will be chosen. The regions of Slovakia where the multimodal logistics object should potentially be placed were identified as those of: Bratislava, Trnava, Trencin, Nitra, Zilina, Banska Bystrica, Presov and Kosice.

For a more accurate result it would be more appropriate to look at district level, but at this level it would be very difficult to obtain data to fulfil the criteria matrix (an essential part of multi-criteria analysis) because most of the data required is not available at district level.

4.2. Establishment of a set of criteria

Stage two of the process of multi-criteria analysis involves establishing a set of criteria which influence the process of decision making in the selection of variants. [4].

From the point of view of formality it is necessary to differentiate the criteria according to the type of preference and the way (form) of expressing and measuring the results of evaluations based on such criteria. Criteria according to their type preference can be placed in order of [5-6]:

- Increasing preference (maximization, profit) - in which higher values are preferred over lower ones,
- Decreasing preference (minimization, loss) - which are the opposite of the above,
- Alternating preference - preference changes when a certain value is achieved.

Criteria by way of expression and measurement of evaluations of results [5-6]:

- Quantitatively, the values of which can be expressed numerically by the number of units of measure,
- Qualitatively, which can only be expressed verbally, i.e. degrees of quality and a description of their intensity.

After determining the objectives of the analysis of available knowledge, relevant to this article, 6 criteria from socio-economic and transport areas were defined. For these criteria critical data were obtained based on the study of the functions and perspectives that are related to the activities carried out in an multimodal logistics object. Due to the prerequisite that all the data (associated with different factors) should be related to the same time period, only data collected for 2010 appears in this article.

For clarity, the criteria (factors) are summarized in the following table (*Table 1*). *Table 2* shows the specific values of criteria related to individual variants (regions in the Slo-

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vak Republic) and it is also the criteria matrix for the purpose of this article.

Table 1. Overview of criteria related to the solution of the problem of multimodal logistics object location

Criteria	Acronym (designation)
GDP per capita (PPS)	GDP
Amount of transported goods via public roads (thousands tonnes)	TGR
Number of small and medium size companies (< 250 employees)	NSE
Population size	NP
State of road network (km)	RN
Regional connections with network of railway lines AGTC	AG

Source: authors according to [3]

Table 2. Actual values of criteria related to individual variants (criteria matrix)

Criterion / Variant	GDP	TGR	NSE	NP	RN	AG
Bratislava	43063	8255	49420	628686	241.75	3
Trnava	20078	5651	13136	563081	360.87	3
Trencin	15823	8921	11781	598819	508.52	2
Nitra	14841	2875	14301	704752	517.99	2
Zilina	15826	4320	13390	698274	593.54	2
Banska Bystrica	13215	3968	12525	652218	733.89	0
Presov	10104	4258	13120	809443	715.43	2
Kosice	14109	6369	14744	780000	371.88	2

Source: [7-8]

4.2.1. Transfer of Criteria to the Same Type

For the purposes of tasks related to the criteria matrix it is appropriate that all the criteria are of the same type (minimization or maximization). Transfer of the criteria to the same type is not difficult because each minimization criterion can be easily converted to maximization criterion [1,2].

1. The scale is given by the nature of the issue. In this case we take the maximum value that can be achieved, and subtract from it the value of the criterion.

2. The scale is not given. In this case, we find the variant with the highest (worst) value and subtract from it the value of the criterion. This step can be presented as protection against the worst variant.

In our case it is not necessary to perform a modification at any criterion, because all the criteria are of the same type (maximization).

4.2.2. Ideal and basal variant

Ideal variant is the best option which can be theoretically or practically achieved.

1. Relative (highest in criteria matrix for a given criterion),
2. Absolute (highest theoretically possible value).

In our case (*Table 3*):

Table 3. Ideal variant

Criterion	Ideal value
GDP	43063
TGR	8921
NSE	49420
NP	809443
RN	733.89
AG	3

Source: authors according to [3]

Basal variant is the worst variant which can be theoretically or practically achieved (*Table 4*).

1. Relative (the lowest value in the criteria matrix for a given criterion),
2. Absolute (the lowest theoretically possible value).

Table 4. Basal variant

Criterion	Basal value
GDP	10104
TGR	2875
NSE	11781
NP	563081
RN	241.75
AG	0

Source: authors according to [3]

4.2.3. Normalization of criteria matrix

If we know the ideal and basal variants, we simply normalize the criteria matrix. All values in the criteria matrix will be in the interval <0,1>, the ideal value of the criteria matrix will then be represented by the number 1 and the basal by the number 0. An important feature of this normalized criteria matrix is that it is completely independent of the units [1,2].

If we mark the basal value for criteria j as D_j and the ideal value for criteria j as H_j then the normalized criteria matrix (r_{ij}) arises from the initial criteria matrix (y_{ij}) as follows:

$$r_{ij} = \frac{y_{ij} - D_j}{H_j - D_j}. \quad (2)$$

In our case, to normalize the criteria matrix the following steps must be performed:

Having a criteria matrix for maximizing criteria, we add lines with the ideal and basal variants (*Table 5*).

Table 5. Adjusted criteria matrix with auxiliary lines with the ideal and basal variants

Criterion / Variant	GDP	TGR	NSE	NP	RN	AG
Bratislava	43063	8255	49420	628686	241.75	3
Trnava	20078	5651	13136	563081	360.87	3
Trencin	15823	8921	11781	598819	508.52	2
Nitra	14841	2875	14301	704752	517.99	2
Zilina	15826	4320	13390	698274	593.54	2
Banska Bystrica	13215	3968	12525	652218	733.89	0
Presov	10104	4258	13120	809443	715.43	2
Kosice	14109	6369	14744	780000	371.88	2
H_j	43063	8921	49420	809443	733.89	3
D_j	10104	2875	11781	563081	241.75	0
$H_j - D_j$	32959	6046	37639	246362	492.14	3

Source: authors according to [3]

$$r_{i1} = \frac{y_{i1} - 10104}{32959}, \quad r_{i2} = \frac{y_{i4} - 2875}{6046},$$

$r_{i3} = \frac{y_{i6}-11781}{37639}, r_{i4} = \frac{y_{i7}-563081}{246362}, \; r_{i5} = \frac{y_{i9}-\frac{24175}{100}}{\frac{49214}{100}}, \; r_{i16} = \frac{y_{i10}}{3}.$

According to the above formulae we set up the required matrix (*Table 6*):

Table 6. Normalized criteria matrix

Criterion / Variant	GDP	TGR	NSE	NP	RN	AG
Bratislava	1	0.890	1	0.266	0	1
Trnava	0.303	0.459	0.036	0	0.242	1
Trencin	0.174	1	0	0.145	0.542	0.667
Nitra	0.144	0	0.067	0.575	0.561	0.667
Zilina	0.174	0.239	0.043	0.549	0.715	0.667
Banska Bystrica	0.094	0.181	0.012	0.362	1	0
Presov	0	0.229	0.036	1	0.963	0.667
Kosice	0.122	0.578	0.079	0.881	0.264	0.667

Source: authors

5. Conclusion

In order to accomplish all steps of the multi-criteria evaluation of variants the above mentioned procedures should be followed by the determination of criteria weightings.

This step can be made using the Saaty pairwise comparison method. This method is able to determine final values of the vector of weights of individual criterion.

Subsequently, the most appropriate variant for the multimodal logistics object location in the Slovak Republic can be determined. One possible approach is to multiply the normalized matrix by the vector of weights indicated by Saaty method. But this article does not deal with this part of the multi-criteria evaluation of variants issue.

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