An integrated approach to decision-making in order to select logistics centre locations

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Multicriteria decision-making (MCDM) models are widely used in selection problems in the literature. Taking into account the significance of selection and ranking of different locations, it is necessary to compare, as objectively as possible, the influences of various criteria and reduce them to a common function, i.e. present the methodology of solving complex problems associated with ranking of alternatives. In this study, an integrated approach which employs fuzzy analytic hierarchy process (F-AHP) and modified preference ranking organization method for enrichment evaluations (MODIPROM) together, is proposed for the optimal logistics centre locations. Changes in the final ranking indicate the importance of determining the relative weights in the process of multicriteria analysis. In order to confirm the results obtained by the combined approach as well as proof of applicability and practicality of the same, the discussed problem is analyzed using standard methods of multicriteria analysis.

Keywords: *location problem, multicriteria decision-making, fuzzy AHP, MODIPROM, sensitivity analysis.*

1. INTRODUCTION

As guidelines for further development were defined, it is necessary to attract capital and influence on the development of production programs or economic activities in favorable locations in the region and at the same time fit into the current trends of moving of goods flows. The need for the development of logistics centres for this purpose is inevitable as well as providing conditions for their quality services. Bearing in mind the strategic orientation of our economy, which envisages the development of small and medium-sized enterprises, there is a need for a new approach to improve the regional economy. In this case there is a need for an efficient and high-quality decision-making.

Logistics centres as an idea and real form have existed for a long time and satisfy a broader set of objectives of different interest groups from national, regional, municipal and city governments to the carriers and users of transport services [12]. A large number of location factors and their heterogeneity clearly indicate that location problems have an interdisciplinary character and frequently require the application of complex procedures in selection of solutions [1], [5], [8], [10], [14]. The existence of several alternatives and criteria, where some of them should be maximized and some should be minimized, means that decisions are made under conditions of conflict and that the instruments which are more flexible than strict mathematical techniques of pure optimization should be applied to solving multicriteria problems. A number of heuristic techniques can be used directly in solving the location problem or adjusted to the aim.

In the meantime, the ability and experience of the decision-maker in the selection of location can significantly affect the final solution. A detailed overview of the efforts and development made so far in the field of multicriteria location problems [8], as well as an overview of utilized criteria and methods for solving the mentioned problems, led to observation that there is a tendency that the methods of "higher-ranking" (outranking methods) are in the foreground, due to their adaptability to the real problems and the fact that compared to similar methods they are very comprehensible to the decision-maker.

In the existing literature, there are numerous examples where the PROMETHEE methods and their modifications are used in the selection of final decisions in solving various multicriteria problems [7], [9], [11], [12].In recent years, the problems referring to group decision-making, subjectivity of the decision-maker and utilization of qualitative expressions for the values of alternatives per individual criterion have been shown by numerous extended methods based on generalized fuzzy numbers [9], [11], [14].

This paper presents a procedure of creation of an efficient method and technique for support to decision-making in such a way that the selection of generalized criteria is not yielded to the experience and subjective evaluation of the decision-maker in order to select a logistics centres location.

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Thus, final order of alternative solutions to a problem depends on applied technique of multicriteria decision-making, and especially on the procedure of defining the evaluation criteria, transformation (normalization) of criteria and determination of their relative significance. Solving the decision-making problem, in the domain of logistics and logistics systems, requires firstly defining the criteria system and later determination of their relative significance. Generally, the Fuzzy-AHP is used to determine the relative weight of criteria and modified PROMETHEE method (MODIPROM) [12] is used to obtain final ranking of alternatives of considered problem. The criteria weights do not have a clearly economic significance, but they are measures for the relative significance of criteria. Obtaining a value of the criteria weight is a particular problem and its solution depends on the structure of preferences of decision-makers and the ways of its expression and formulation.

The proposed model minimizes the influence of experience and subjective evaluation of the decision-maker in the selection of generalized criteria, i.e. the selection is performed on the basis of the methods of the least squares. Also, we can analyze the effects of changing the weight coefficients, and for each criterion function it is possible to see the forms of adopted generalized criteria and the positions of their respective experimental points, which is a significant contribution and basis for solving complex problems of multicriteria analysis by complex criteria. Practicability, efficiency and applicability of the proposed method in the selection of logistics centre location are presented through the analysis of a numerical example.

2. FUZZY AHP AND MODIPROM METHODS

The final ranking of the alternatives depends on the applied techniques for decision-making, especially on the process of defining the criteria for the evaluation, transformation (normalization) of criteria and determining their relative importance. When the relative importance of the criteria is in question, each criterion is assigned the corresponding weight value, based on expert assessments and evaluations of other participants in decision-making, which is why it is advisable to include a broader range of experts and all other stakeholders. From a review of the literature [6], it can be noted that the most common approach for this purpose in a large number of papers is the analytic hierarchy process - AHP. Subjective decisions are crucial in the process of determining the relative weight of criteria, and there is a tendency in literature to express subjective attitude on the weights of criteria (significance) through pairwise comparing of criteria.

However, the classical technique makes the process of comparison too complicated for collecting the assessment of decision-makers, so fuzzy logic, i.e. fuzzy AHP technique [15] is used in order to eliminate this shortcoming in the comparison at all hierarchical levels of problem. Fuzzy logic is proved to be excellent in models in which intuition and evaluation are the primary elements.

The theory of fuzzy sets was applied because of frequent actions of decision-makers in terms of vagueness or so-called partial truth.

2.1 Fuzzy AHP

Fuzzification of conventional AHP method was carried out by using triangular fuzzy numbers and interval arithmetic to determine the weights of criteria and alternatives, starting from the scale of the relative importance and evaluation in pairs including all necessary matrix operations. Triangular fuzzy numbers are used to improve the process of scaling in the formation of comparison matrix, while fuzzy arithmetic is used to determine the fuzzy vector eigenvalues.

The procedure of this approach can be presented in several steps [6]:

Step 1: The determination of criteria weights i.e. the relative strength of the two elements at the same level of hierarchy by using triangular fuzzy numbers $(\tilde{1},\tilde{3},\tilde{5},\tilde{7},\tilde{9})$.

Step 2: The formation of fuzzy comparison matrix $\tilde{A}(a_{ij})$ as:

$$\tilde{A}=\begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & & 1 \end{bmatrix} \quad (1)$$

where:

$$\tilde{a}_{ij}=\begin{cases} \tilde{1},\tilde{3},\tilde{5},\tilde{7},\tilde{9} & i>j \\ 1 & i=j \\ \tilde{1}^{-1},\tilde{3}^{-1},\tilde{5}^{-1},\tilde{7}^{-1},\tilde{9}^{-1} & i<j \end{cases}$$

Step 3: The determination a fuzzy eigenvalues, which represents the solution of the system:

$$\tilde{A}\tilde{x}=\tilde{\lambda}\tilde{x} \quad (2)$$

$\tilde{A}$ is - n x n fuzzy matrix which contains fuzzy numbers $\tilde{a}_{ij}$, $\tilde{x}$ is a n x 1 fuzzy eigenvector containing the fuzzy numbers $\tilde{x}_i$.

Interval arithmetic is used for all operations, i.e. interval arithmetic and methods of α-cuts are used for multiplication and addition of fuzzy number [6], and the equations are:

$$\begin{aligned} &\forall\alpha\in[0,1] \\ &\tilde{A}\alpha=[l\alpha,u\alpha]=[(m-l)\alpha+l,u-(u-m)\alpha] \end{aligned} \quad (3)$$

$$\begin{aligned} a_{i1l}^{\alpha}x_{il}^{\alpha}+\cdots+a_{inl}^{\alpha}x_{nl}^{\alpha}&=\lambda x_{il}^{\alpha} \\ a_{i1u}^{\alpha}x_{iu}^{\alpha}+\cdots+a_{inu}^{\alpha}x_{nu}^{\alpha}&=\lambda x_{iu}^{\alpha} \end{aligned}$$

$$\tilde{a}_{ij}^{\alpha}=\left[a_{i1l}^{\alpha},a_{i1u}^{\alpha}\right],\tilde{x}_i^{\alpha}=\left[x_{il}^{\alpha},x_{iu}^{\alpha}\right],\tilde{\lambda}^{\alpha}=\left[\lambda_l^{\alpha},\lambda_u^{\alpha}\right]$$

for $0<\alpha\leq 1$ и *i=1,2,…,n, j=1,2,…,n.* (4)

where: *l*-lower limit and *u*-upper limit of fuzzy number (*l, m, u*).

The degree of satisfaction can be obtained from decision-maker by index of optimism λ. The larger the index λ, the higher the degree of satisfaction [6]:

$$\tilde{a}_{ij}^{\alpha} = \lambda a_{iju}^{\alpha} + (1-\lambda) a_{ijl}^{\alpha}, \forall \lambda \in [0,1] \quad (5)$$

The degree of satisfaction and reconstructed matrix can be estimated by fixing parameter α and setting the index of optimism λ, as follows:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12}^{\alpha} & \cdots & \tilde{a}_{1n}^{\alpha} \\ \tilde{a}_{21}^{\alpha} & 1 & \cdots & \tilde{a}_{2n}^{\alpha} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}_{n1}^{\alpha} & \tilde{a}_{n2}^{\alpha} & & 1 \end{bmatrix} \quad (6)$$

The five triangular fuzzy numbers are defined with corresponding intensity of importance (Figure 1).

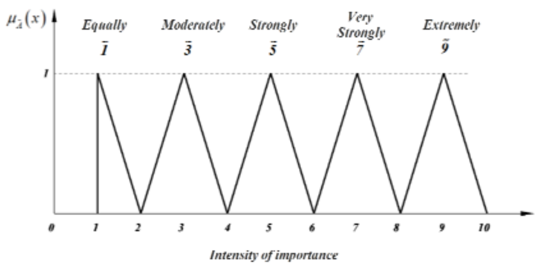


Figure1. Fuzzy membership function

The consistency index (CI) and consistency ratio (CR) are given as follows:

$$CI = (\lambda_{\max} - n)/(n-1) \quad (6)$$
$$CR = CI / RI$$

For the purposes of further research and easier application of the proposed algorithm for obtaining the relative weights of criteria (Figure 2), the program tool is developed using MATLAB programming. The developed program is integrated at a later stage with a tool developed for the purpose of ranking of alternatives and it is characterized by the ability to use an unlimited number of criteria as well as speed and flexibility. Besides, the developed tool enables decision-makers to use different values of the confidence level and index of optimism as input in the interval [0, 1] and to show their influence on the final results. Thus, the process of evaluating and determining the criteria preference is implemented as follows:

- Preparing the input data (number of criteria and alternatives, the value of the confidence level and index of optimism).
- Generating the fuzzy comparison matrix. Fuzzy comparison matrix is square in size, equal to the number of criteria, values 1 are on the main diagonal, and other values in the form of triangular fuzzy numbers are entered as a result of pairwise comparisons of each criterion on each level based on the scale of five points (Figure 1). In this step, only direct values are entered while the inverted ones are automatically generated.
- Applying (4) and (5), the program automatically generates α-cut matrix.
- Normalizing the matrix from the previous step, calculating the fuzzy eigenvalues i.e. finding the relative weights of criteria and consistency index and ratio in accordance with the fuzzy AHP approach. If the consistency ratio is less than 0.10, the result is sufficiently accurate and there is no need for correction in pairwise judgment and repetition of calculation.

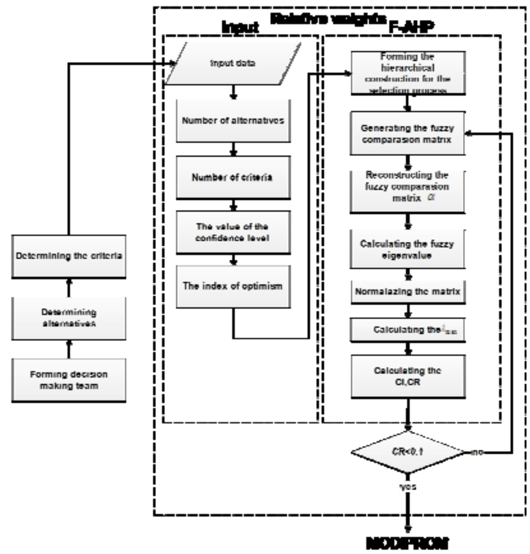


Figure 2. Algorithm for obtaining the relative weights of criteria

2.2 MODIPROM method

The next phase deals with selection of multicriteria analysis methods and predefined alternatives are evaluated on the basis of the adopted criteria and their relative weights. Selection of the best multicriteria method is completely defined by the nature of the observed problems. The proposed procedure is based on the improvement of the family of methods for multicriteria ranking. Thus, the problem is interesting both from the theoretical and practical aspects.

The proposed MODIPROM method (MODIfied PROmethee Method) [12], [13] is based on the improvement of a group of methods for multicriteria ranking, as follows:

- change of the existing generalized criteria and introduction of the new ones,
- procedure of selection of generalized criteria within one criterion function,
- analysis of effects of change of weight coefficients, and
- transformation of the mean values of the outranking flow for the purpose of solving complex criterion functions.

Also, the proposed procedure is based on the improvement of the family of methods for multicriteria ranking through a change of the existing generalized criteria and introduction of the new ones.

Changes of generalized criteria refer to retaining generalized criteria type I (Usual criterion), type II (U-shape criterion), type IV (Level criterion) and type VI (Gaussian criterion).Criterion type III (V-shape criterion) and type V (V-shape with indifference criterion) are replaced with the linear criterion whose parameters are calculated through linear regression. The square and cube criteria whose parameters are calculated by regression analysis are introduced (Figure 3).

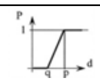
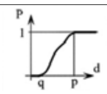
TYPE OF GENERALIZED CRITERION			Parameters	$P_j(x)$
Type	Name	Shape		
III	Criterion with linear preference		q, p, b0, b1	$P_j(x)=\begin{cases} 0, & d<q \\ b_0+b_1x, & q\le d<p \\ 1, & d\ge p \end{cases}$
V	Square criterion		q, p, b0, b1, b2	$P_j(x)=\begin{cases} 0, & d<q \\ b_0+b_1x+b_2x^2, & q\le d<p \\ 1, & d\ge p \end{cases}$
VI	Cube criterion		q, p, b0, b1, b2, b3	$P_j(x)=\begin{cases} 0, & d<q \\ b_0+b_1x+b_2x^2+b_3x^3, & q\le d<p \\ 1, & d\ge p \end{cases}$

Figure 3. Changes of generalized criteria (q – the threshold or indifference, p – the threshold of strict preference, σ – the standard deviation of Normal distribution and b0, b1, b2, b3 – the coefficients of the regression line)

The influence of experience and subjective assessment of decision-maker in the selection of generalized criteria was reduced to a minimum, by changing the existing and implementation of new generalized criterion i.e. the generalized criterion in which the sum of squares of deviations of experimental points from the theoretical curve is the least is chosen on the basis of the method of the least squares. It should be noted that the choice of the type of generalized criterion solves the problem of normalization criterion values, because the preferences of the individual criteria are distributed in the interval [0, 1]. Thus the impact of measurements diversity of individual criteria is avoided.

The complete procedure of implementation of the MODIPROM method [12] is described by the following steps:

***Step 1**: Selection of the preference function*

After the matrix creation phase, one preference function P_j (a_i, a_k) is assigned to each criterion for which two alternatives are compared. Based on the preference functions, a type of generalized criterion function which has the value between 0 and 1 is selected.

It is necessary to create tables of difference $(d_{ik})_j=f_j(a_i)- f_j(a_k)$ and a series of positive differences $(d_{ik})_j>0$, and then rank the data d_{ik} according to their size, where $l=1,...,s$. The threshold or indifference - q and the threshold of strict preference - p are determined by the expression: $q_j=\frac{1}{3}d_j \max$ and $p_j=\frac{2}{3}d_j \max$.

For all values $(d_{ik})_j$ and there can be at most $m(m-1)/2$ of them, the value of approximation error is calculated $\varepsilon_l=[p_j(x_{jl})-y_{jl}]$. Out of all generalized criterion functions for the given set of points $\{(d_{ik})_j, P_{jik}(d_{ik})_j\}$, a function which is best in terms of the least squares, i.e. the function whose sum of squares is the least is chosen:

$$S=\sum_{l=1}^{s}\varepsilon_i^2=\sum_{l=1}^{s}\left[p_j\left(x_{jl}\right)-y_{jl}\right]^2 \tag{7}$$

where ε_l – the error of approximation of empirical values of the preferential function y_{jl} by the value of the theoretical function $p_j(x_{jl})$ for the l-th empirical datum and the l-combination of alternatives a_i and a_k for which $(d_{ik})_j=f_j(a_i)- f_j(a_k)>0$, i.e.

$$P_{jik}\left[\left(d_{ik}\right)_j\right]=\begin{cases} 0, \text{ for } \left(d_{ik}\right)_j<0 \\ P_j\left[\left(d_{ik}\right)_j\right], \text{ for } \left(d_{ik}\right)_j>0 \end{cases} \tag{8}$$

where: P_j $(d_{ik})_j$- the selected function of the generalized criterion.

***Step 2:** Calculation of the preference index for each pair of alternatives (Π)*

For each pair of alternatives (a_i, a_k), the preference index is determined by the expression

$$\Pi(a_i,a_k)=\frac{\sum_{j=1}^{n}\omega_j P_j(a_i,a_k)}{\sum_{j=1}^{n}\omega_j},\ \text{j=1,...,n} \tag{9}$$

where each criterion is assigned a certain weight ωj, $j=1,\ldots,k$.

***Step 3:** Calculation of the values of flows (Φ)*

In accordance with the preference index and the expressions (11), the input, output and outranking (pure) flows of action are defined for each alternative. The transformation by expression (7) is performed on the basis of the mean values of net outranking flow Φ.

***Step 4:** Generation of final ranking*

The ranking procedure is performed through the following phases: forming the table of partial ranking according to the Promethee I method, forming the table of complete ranking according to the Promethee II method and forming the table of interval ranking according to the Promethee III method. Through comparative analysis of the results the decision-maker receives information that could assist in selecting the best alternative. The developed appropriate software tool - MODIPROM allows us to see the form of adopted generalized criteria and the position of their respective experimental points for each criterion function [12].

2.3 Proposed integrated approach

The integrated approach is a combination and expansion of some formulated models for determining the relative weights and the ranking of alternatives of considered problem and for a sensitivity analysis of the final order of alternatives due to changes in criteria relative weights. Combination of the methods for reducing the number of independent criteria, methods for determining the relative importance of the criteria and modified methods for ranking of alternatives leads to making optimal decisions on these problems regardless of the nature of the parameters that describe it. The proposed algorithm of integrated approach, with all the above elements, is shown in Figure 4.

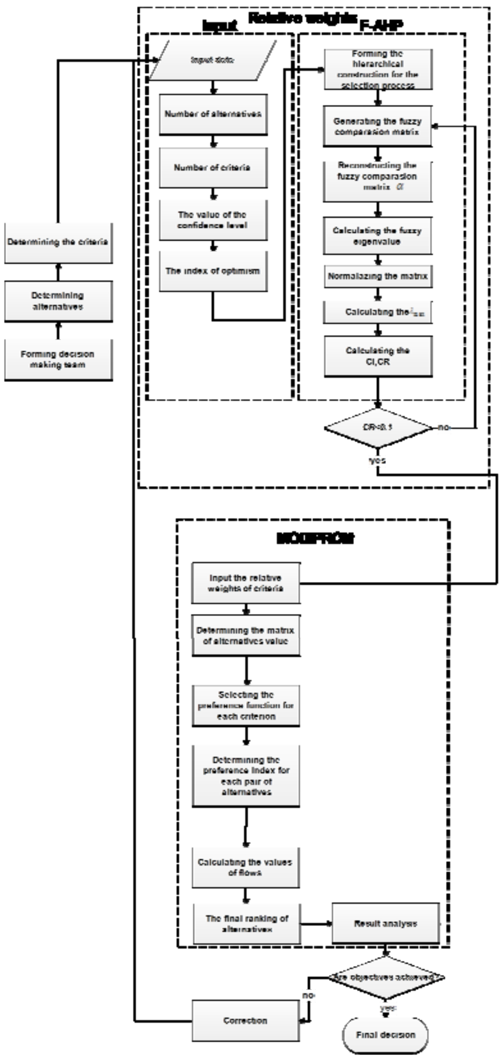


Figure 4. The integrated approach

3. A NUMERICAL APPLICATION OF PROPOSED APPROACH

Therefore, the problem of strategic decision-making, given in the introduction, is formulated through ranking alternatives of potential location for future regional logistics center. Based on many years of practical experience and the results of previous studies, projects and research, conclusions have been drawn about the justification of planning, construction and commissioning of the regional logistics center. Very useful solution of business improvement in the regional framework is the formation and development of regional logistics centers with centralized industrial warehouse.

Preconditions used in this study lie in the fact that, bearing in mind the problems of freight transport in urban areas in general, as well as the geographical position of the region in which the central position is occupied by the city of Kraljevo, increase of the level of total trade in the region and planned industrial development (after privatization, re-engineering of equipment and technologies) it can be concluded that the conditions were created for the project of development of regional city (urban) logistics and the new concept of centralized industrial warehouse.

3.1 Definition of potential locations

The defining of potential locations was based on consideration of the data of foreign trade exchange of Serbia, i.e. the observed region. Based on data on the share of individual regions in imports and exports, in order to reduce the problem, five most economically developed municipalities of the region were isolated and observed as the main destination of goods flows, i.e. as places of potential location of the future logistics center (Figure 5). Notable is the fact that Kraljevo has the position of the central unit within the Region. The proximity of other municipalities is such that the transport can be considered to take place "within the city area". The idea is to present the current problem of the choice of location at the macro level and at the same time to solve it by using the tools included into the contemporary mathematic field of decision-making theory. Therefore, a special attention was focused more on the need for a more objective comparison of the impact of various individual criteria and their nature in the process of selection of an optimum location, than the act of formation of potential locations, i.e. alternatives of considered problem. The main role in the decision-making process of the considered problem belongs to the local government which represents the public sector and operator representing the private sector.

Figure 5. Potential locations for the regional logistics center with the gravitational zone

3.2 Identification of factors that influence on the choice of location and determine the relative weights of criteria

The criteria can be generated and classified according to various aspects of the system observation and decision-makers.

For this purpose, in order to guarantee the successful construction and development of a logistics center for the selected region, criteria or subcriteria based on expert knowledge and previous experience are classified into five different groups (Tables 1 and 2). The complexity and multiplicity of objectives and criteria of different stakeholders are obvious. The level of sub criteria depends on the settings of location problems. Besides, all criteria are not mentioned, and all of those that are listed may not be applied to concrete location problems.

Table 1. Key factors for locating the logistics center

Criteria	Label of criteria	Relative weights	Label of subcriteria	Relative weights of subcriteria
Technological	K_I	25%	K_{11}	40%
			K_{12}	40%
			K_{13}	20%
Social/ labour	K_{II}	15 %	K_{21}	15%
			K_{22}	20%
			K_{23}	25%
			K_{24}	25%
			K_{25}	15%
Legal-regulatory framework	K_{III}	10%	K_{31}	30%
			K_{32}	30%
			K_{33}	20%
			K_{34}	20%
Economical	K_{IV}	25%	K_{41}	30%
			K_{42}	30%
			K_{43}	30%
			K_{44}	10%
Technical	K_V	25%	K_{51}	10%
			K_{52}	30%
			K_{53}	30%
			K_{54}	30%

Table 2. Key subcriteria for locating the logistics center

Label	Subcriteria – 2nd level
K_{11}	Road transport system-distance from highway- (km)
K_{12}	Effective railway transport system- (points)
K_{13}	Airport access-min distance - (km)
K_{21}	Unemployment rate - (points)
K_{22}	Alleviate unemployment - (%)
K_{23}	Availability of specialized technicians - (points)
K_{24}	Availability of trained technical labours - (points)
K_{25}	Availability of untrained technical labours - (points)
K_{31}	Availability of land - (points)
K_{32}	Possibility of regulating ownership over land and facility – (points)
K_{33}	Coordination with the spatial and urban plans - (points)
K_{34}	Coordination with the laws regulating environmental protection - (points)
K_{41}	Costs of location activation - (euro/m^2)
K_{42}	Average cost of infrastructure (water/sewerage system)- (euro/m^3)
K_{43}	Investment in construction of access routes and infrastructure - (points)
K_{44}	Period of return on funds - (months)
K_{51}	Geological characteristics of the location - (points)
K_{52}	Technical possibilities for connection with the infrastructure of railway transportation - (points)
K_{53}	Technical possibilities for connection with the infrastructure of water transportation - (points)
K_{54}	Technical possibilities for connection with the infrastructure of road transportation - (points)

In the process of selecting criteria their power is important in terms of selective action on alternative solutions of centers location.

Generation and classification of criteria according to the technological, economic, environmental, legal and regulatory, organizational and technical character, give a possibility of selection and detecting deficiencies of location alternatives in terms of important areas for the development of logistics centers. The selection of criterion from the above mentioned groups is the guarantee of their successful creation, development and sustainability.

3.3The process of evaluation of alternatives, analysis of the results and sensitivity

The application of described methodology of determining the relative weights was performed using the software tool developed for this purpose (Figure 6). The program automatically generates α-cuts matrix, performs normalization of the matrix from the previous step and determines the fuzzy eigenvalues i.e. the relative weights of criteria (Figure 7) and the consistency ratio.

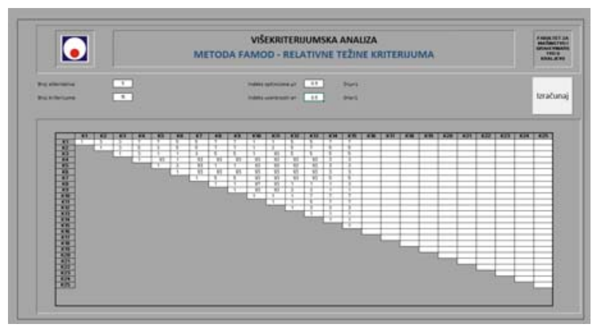


Figure 6. User interface of RTK program [13]

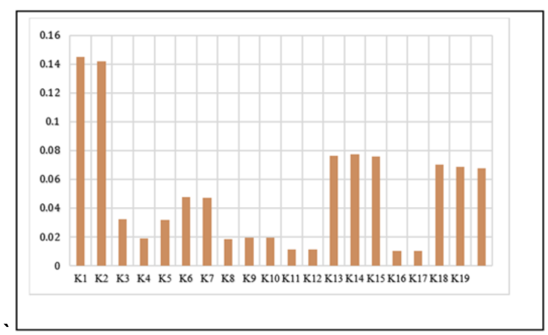


Figure 7. Relative weights of criteria

Table 3. The maximum of eigenvalue and the consistency ratio

The maximum of eigenvalue λ_{max}	21.90690448
The consistency index CI	0.100363394
The consistency ratio CR<0.1	0.061421906

Based on results we can see the importance of the criteria in a group of technical, economic and technological factors in the process of selecting the suitable location relative to the social, legal and regulatory factors.

At this stage, predefined alternatives are evaluated on the basis of the adopted criteria and their relative weights.

After defining given criteria for each alternative and the corresponding transformation of criterion type min. in the type max. (Table 4), the values of the standard deviation in accordance with the expression (7) for each criterion are given in Table 5.

Table 4. Input data for multicriteria analysis

Criteria		Alternatives					ω_j	max/ min
		A_1	A_2	A_3	A_4	A_5		
K_I	K_{11}	26	75	164	80	24	0.145	min
	K_{12}	4	5	2	3	3	0.142	max
	K_{13}	60	10	109	35	70	0.032	min
K_{II}	K_{21}	23	21.1	39	16.6	21	0.019	min
	K_{22}	0.6	0.65	0.8	0.65	0.6	0.032	max
	K_{23}	4	3	2	3	2	0.048	max
	K_{24}	3	3	2	3	3	0.047	max
	K_{25}	3	3	3	3	3	0.018	max
K_{III}	K_{31}	4	3	2	2	2	0.020	max
	K_{32}	3	2	2	3	3	0.019	max
	K_{33}	4	3	2	3	3	0.011	max
	K_{34}	3	3	2	3	3	0.011	max
K_{IV}	K_{41}	54	60	56	55.2	40.8	0.076	min
	K_{42}	0.82	0.93	0.64	0.36	1.3017	0.077	min
	K_{43}	2	3	4	3	2	0.076	min
	K_{44}	60	84	120	72	72	0.010	min
K_V	K_{51}	3	3	2	3	3	0.010	max
	K_{52}	4	4	2	4	4	0.070	max
	K_{53}	2	4	1	3	3	0.069	max
	K_{54}	4	3	2	4	3	0.068	max

Table 5. Standard deviation of criteria

Criteria	σ	S- the sum of squares of generalized criterion function						
		Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII
K1	50.874	2.8500	2.0500	0.06302	0.2500	0.05683	0.04259	0.08736
K2	1.0198	2.5185	0.8519	0.15995	0.5185	0.14815	2.51852	0.17737
K3	33.391	2.8500	2.0500	0.04051	0.3000	0.02209	0.01237	0.01330
K4	7.721	2.8500	1.0500	0.07384	1.0500	0.05561	0.02372	0.43897
K5	0.0735	2.1875	0.6875	0.09606	0.6875	0.09375	1.21339	0.21212
K6	0.7483	2.1875	1.4375	0.28125	0.3125	2.18750	2.18750	0.42410
K7	0.4	0.8750	0.8750	1.87500	0.8750	1.87500	1.87500	0.75091
K8	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K9	0.8	1.8571	0.7143	0.14286	0.2857	2.85714	4.00000	0.30915
K10	0.4899	1.5278	1.5278	2.52778	1.5278	2.52778	2.52778	0.99823
K11	0.6325	1.8571	1.8571	0.35714	0.3571	1.85714	1.64425	0.63067
K12	0.4	0.8750	0.8750	1.87500	0.8750	1.87500	1.87500	0.75091
K13	6.5189	2.8500	1.0500	0.05731	1.0500	0.03990	0.01643	0.33602
K14	0.3123	2.8500	2.0500	0.03650	0.4500	0.01273	0.00590	0.01142
K15	0.7483	2.1875	1.4375	0.28125	0.3125	2.18750	2.18750	0.42410
K16	20.646	2.5185	1.1852	0.07555	0.4630	0.07242	0.06914	0.16515
K17	0.4	0.8750	0.8750	1.87500	0.8750	1.87500	1.87500	0.75091
K18	0.8	0.8750	0.8750	1.87500	0.8750	1.87500	1.87500	0.75091
K19	1.0198	2.5185	0.8519	0.15995	0.5185	0.14815	2.51852	0.17737
K20	0.7483	2.1875	1.4375	0.28125	0.3125	2.18750	2.18750	0.42410

Table 6. The values of index of preference

		The values of index of preferences P(a,b) relative to alternatives					
		A1	A2	A3	A4	A5	**Output flow**
Examined alternatives	A1	0	0.2297117	0.6937314	0.2076856	0.201672	**1.33280**
	A2	0.13662751	0	0.6066185	0.170472	0.234659	**1.14838**
	A3	0.04494796	0.0835129	0	0.022	0.099746	**0.25021**
	A4	0.10107934	0.1569836	0.5737929	0	0.159642	**0.99150**
	A5	0.10754126	0.1931327	0.5954057	0.1638562	0	**1.05994**
	Input flow	**0.39019606**	**0.6633409**	**2.4695485**	**0.5640138**	**0.695719**	

The results of multicriteria analysis are displayed in the form of report presenting a final order of the alternatives PROMETHEE I, PROMETHEE II and PROMETHEE III as well as a graph of interval order of alternatives (Figure 8).

PROMETHEE I		PROMETHEE II		PROMETHEE III	
Rank		Rank		Rank	
4	A1	4	A1	4	A1
2	A2	3	A2	1	A2
1	A4	2	A4	1	A4
1	A5	1	A5	1	A5
0	A3	0	A3	0	A3

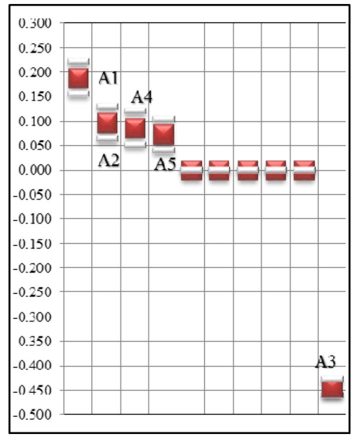


Figure 8. Final ranking of alternatives

In the observed numerical example, the decision-maker, from macro level of observing the choice of location, makes the final decision on locating the logistics center, i.e. conceptual solution (alternative 1) exceeds all present potential limitations and represents the best solution. In order to confirm the results obtained by the integrated approach as well as to prove its applicability and practicability, the problem is also analyzed using standard methods for multicriteria analysis (Fuzzy-AHP approach, TOPSIS method and family of PROMETHEE methods). The obtained results are shown in Table 7 and Figure 9.

Table 7. A comparative analysis of the results of multicriteria analysis methods

Integrated approach FAMOD	FUZZY-AHP	TOPSIS	PROMETHEE (Visual PROMETHEE)
A1	**A1**	**A1**	**A1**
A4	A5	A5	A5
A5	A2	A4	A4
A2	A4	A2	A2
A3	A3	A3	A3

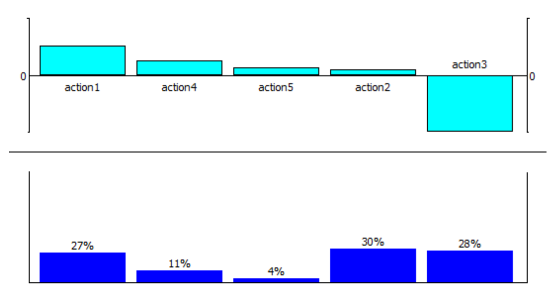


Figure 9. Final ranking of alternatives

After choosing a method of ranking, the last phase in the multicriteria analysis is the study of the stability of solutions (the best alternative, final rank of alternative or a subset of good alternatives) on certain changes in the input data.

Of course, the study of stability of solutions to changes in the relative weights of the criteria, as a kind of representative of subjectivism in multicriteria decision analysis, is the most interesting. In this case, there are two criteria, k_1 and k_2, having the most impact on the alternatives. The values of these criteria were changed in increments -25%, -10%, + 10% and + 25%, while the values of other criteria are customized in such a way that the sum total of their weights is always 1. The results of the conducted analysis are given in Table 8. It can be seen that the weight changes of observed criteria for the value of +10%, +25% and -10% do not lead to changes in the final rank of alternatives, but the change in value of -25% causes the last two alternatives to change the position in the final order. In all cases the most optimal variant remains unchanged, which indicates the robustness of the proposed approach in resolving these types of multicriteria tasks.

Table 8. The sensitivity analysis of the problem

Alternatives	Increase of relative weights		Decrease of relative weights		Integrated approach FAMOD
	25 %	10 %	10 %	25 %	
A1	1	1	1	1	1
A2	4	4	4	4	4
A3	5	5	2	2	5
A4	2	2	5	5	2
A5	3	3	3	3	3

4. CONCLUSION

The proposed approach is a combination and expansion of some models formulated so far. In literature and in this approach there is a tendency to edit and possibly standardize multicriteria methods, where the major premise is that it is easier to express subjective attitude on relative weights of the criteria by comparing criteria pairwise rather than all at once. Setting the value of the weight criteria is a particular problem and its solution depends on the structure of preferences of decision-makers and the manner of its expression and formulation. The developed tool enables decision-makers to use different the value of the confidence level and the index of optimism within the interval [0,1] and to show their influence on the final results. The specificity of the above approach is a function of preference, change in existing generalized criteria and the introduction of new ones, automated procedure for the selection of generalized criteria and analysis of the influence of changes in relative weights on the final order of the alternatives. The proposed method could be extended with the fuzzy theory set. The possibility of taking into account the linguistic expressions of the importance and value of alternative criteria as well as reduction of the number of criteria on operational and acceptable level are the directions of further researches. Such analyses would result in the formation of a comprehensive tool for solving a wide range of real and practical problems.

REFERENCES

[1] Avittathur, B., Shah, J. and Gupta, O. K.: Distribution centre location modelling for differential sales tax structure, European Journal of Operations Research 162: 191–205, 2005.

[2] Behzadian, M., Kaemzadeh, R. B., Albadvi, A., and Aghdasi, M.: PROMETHEE: A comprehensive literature review on methodologies and applications, European Journal of Operations Research 200:198–215, 2009.

[3] Brans, J. P., Mareschal, B. and Vincke, P.: PROMETHEE: A new family of outranking methods in MCDM. IN J: P: Brans (Ed.), Operational research' 84: 477–490, 1984.

[4] Chen, C.-T.: A fuzzy approach to the select of the location of distribution center, Fuzzy Sets and Systems 118:65-73, 2001.

[5] Chu, T. -C. and Lai, M. -T. : Selecting distribution centre location using an improved fuzzy MCDM approach, The International Journal of Advanced Manufacturing Technology 26: 293–299, 2005.

[6] Dagdeviren, M.: Decision Making in equipment selection: an integrated approach with AHP and PROMETHEE, Journal of Intelligent Manufacturing, 19,397-406,2008.

[7] Dias, L., Costal, J. P. and Clímaco, J. N.: A parallel implementation of the PROMETHEE method, European Journal of Operations Research 104: 521–531, 1998.

[8] Farahani, R. Z. and Asgari, N.: Combination of MCDM and covering techniques in hierarchical model for facility location: A case study, European Journal of Operations Research 176: 1839–1858, 2007.

[9] Goumas, M. and Lygerrou, V.: An extension of the PROMETHEE method for decision making in fuzzy environment: Ranking of alternative energy exploitation projects, European Journal of Operations Research 123: 606–613, 2000.

[10] Klapita, V. and Švecová, R.: Logistic centres location, Transport 21(1): 48–52, 2006.

[11] Li, W.-X. and Li, B.–Y.: An extension of the Promethee II method based on generalized fuzzy numbers, Expert Systems with Applications, Expert Systems with Applications, 37(7):5314-5319, 2010.

[12] Marković, G., Gašić, M., Kolarević, M., Savković, M. and Marinković, Z.: Application of the MODIPROM method to the final solution of logistics centre location, Transport 28(4), pp. 341-351, 2013.

[13] Marković, G.: Model of regional logistics with transport systems, PhD Thesis, pp. 183, 2014.

[14] Tabari, M., Kaboli, A., Arzaneyhad, M. B., Shahanaghi, K. and Siadat, A.: A new method for location selection: A hybrid analysis, Applied Mathematics and Computation 206: 598–606, 2008.

[15] Taha, Z. and Rostam, S.: A hybrid AHP-PROMETHEE decision support system for machine tool selection in flexible manufacturing cell, J. Intell. Manuf. (2012) 23:2137-2149, 2012.

