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EVALUATION OF OPTIMAL LOCATION SELECTION CRITERIA USINGANF-AHP APPROACH

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Abstract

The selection procedure is not sufficiently structured, depends on broad areas of knowledge, and requires the use of efficient and effective tools for decision-making. 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 present the methodology of solving complex problems associated with ranking of alternatives. In this study, acombined approach which employs the fuzzy analytic hierarchy process (F-AHP) and methods for ranking of alternativesis proposed for the optimallogistics centre location. Changes in the final ranking indicate the importance of determining the relative weights.In order to confirm the results obtained by the proposed approach as well as proof of applicability and practicality of the same, the discussed problem is analyzed using standard and modified methods of multicriteria analysis.The purpose of this paper was to give systematic review and adequate support for decision-making in the selection procedure.

***Keywords**: multicriteria decision-making,fuzzy AHP,location,criteria, relative weights*

1 INTRODUCTION

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 [6].

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], [2], [45], [9].

MCDM methods are the most common approach type applied for selection of logistic centres location. MCMD models try to answer the question of "what is the best alternative?" given a set of selection criteria and a set of alternatives. So, within the application of MCDM model, mostly the carrying out of the following steps is required [10]:defining relevant criteria and alternatives,giving numerical values for relative importance (weights), as well as alternatives influence on these criteria and getting numerical values that determine final result of alternatives ranking.Decision maker, in great number of such real problems, must meet one or more goals as well as the numerous conflict criteria.

This paper presents a systematic overview and adequate support for decision-making in domain of logistic systems.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 research in this study is directed to the possibility of analyzing the effects of change the weight coefficients and further correlation test application for comparing the independent criteria and reduction of their number to operational and acceptable level.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 AHP AND FUZZY AHP

The finalrankingof thealternativesdepends on the processof defining thecriteria for the evaluation, transformation (normalization) of criteria and determiningtheir relativeimportance.Whenthe relativeimportance of thecriteria is in question, each criterionis assigned the correspondingweightvalue, based on expertassessments and evaluationsof otherparticipants indecision-making, which is why it is advisableto includea broader range ofexperts andallother stakeholders.

From a review ofthe literature [4], it can be notedthat the most commonapproach forthis purposein a largenumber of papers is the AnalyticHierarchyProcess(AHP). Subjectivedecisionsare crucial in the processof determining therelativeweightof criteria, and there is a tendency in literature to express subjectiveattitudeon the weightsof criteria(significance) through pairwise comparing ofcriteria.AHP is a mathematical method which takes into account the priorities of individuals or groups and evaluates combinations of qualitative and quantitative variables in decision-making. AHP is based on three principles: decomposition of a complex unstructured problem, comparative judgments about the problem and synthesis of priorities derived from the judgments[11].

The AHP technique uses a one-way hierarchical relation with respect to decision layers (Fig. 1).

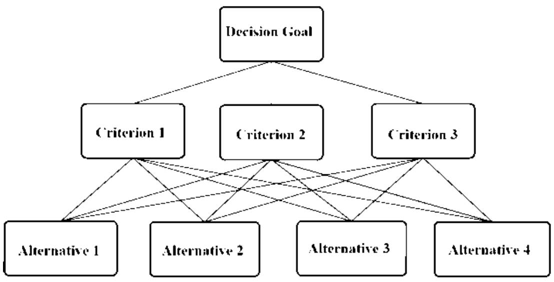


Fig. 1*Hieararchy for a typical three-level MCDM problem*

The classical techniquemakes the processof comparisontoocomplicatedfor collectingthe assessmentof decision-makers, sofuzzylogic, i.e. fuzzyAHPtechnique[10] is used inorder to eliminatethis shortcomingin the comparisonat all hierarchicallevels ofproblem.Fuzzy logic is proved to beexcellentin modelsin whichintuitionand evaluation are the primaryelements. 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 [10]:

Step 1: The determination of criteria weights i.e. the relative strength ofthetwo elementsat the same levelof hierarchy by usingtriangularfuzzy numbers $(\tilde{1},\tilde{3},\tilde{5},\tilde{7},\tilde{9})$.

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

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

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 fuzzyeigenvalues, which representsthe solutionof the system:

$$\tilde{A}\tilde{x}=\tilde{\lambda}\tilde{x} \tag{2}$$

$\tilde{A}$ 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 $\tilde{x}_i$ .Intervalarithmetic is used for all operations,i.e. intervalarithmetic and methods of α-cuts are used for multiplicationand addition of fuzzy number[9], and the equations are:

$$\forall\alpha\in[0,1]$$
$$\tilde{A}\alpha=[l\alpha,u\alpha]=\left[(m-l)\alpha+l,u-(u-m)\alpha\right] \tag{3}$$

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

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

for $0<\alpha\leq1$ and*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 [9]:

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

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

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

The five triangular fuzzy numbers are defined with corresponding intensity of importance (Fig.2).

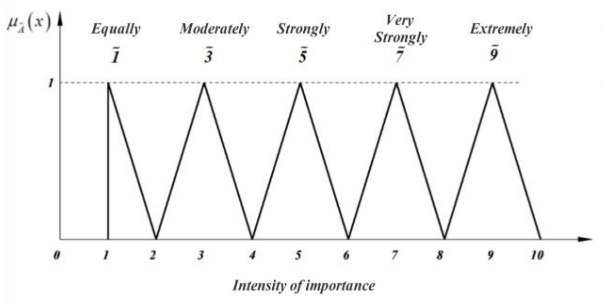


Fig. 2 *Fuzzy membership function*

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

$$CI=\left(\lambda_{\max}-n\right)/\left(n-1\right) \tag{7}$$
$$CR=CI/RI$$

For the purposesof further researchand easier applicationof the proposedalgorithmfor obtainingthe relativeweightsof criteria (Fig. 3), the program toolis developedusingMATLAB programming[7]. The is characterized bythe ability to usean unlimited number ofcriteriaas well asspeed andflexibility.Besides, the developed toolenablesdecision-makers to use differentvalues of the confidence leveland index of optimismas inputin the interval[0, 1] and to showtheir influenceon the final results. Thus, the processof evaluatinganddetermining thecriteriapreference is implementedas follows:

1. **Preparing the input data**(number ofcriteria and alternatives, the value of the confidence leveland index of optimism).
2. **Generating the fuzzycomparisonmatrix**. 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 (Fig.2). In this step, only

direct values are entered while the inverted ones are automatically generated.

3. **α-cut matrix.**Applying(4) and (5), the program automatically generatesα-cut matrix.

4. **Normalizing thematrix**from the previous step, calculatingthefuzzyeigenvaluesi.e. finding the relativeweightsof criteria and consistency index and ratio in accordance with the fuzzy AHP approach.If the consistency ratio is less than0.10, the result is sufficiently accurateandthere is no needforcorrection in pairwise judgmentandrepetition of calculation.

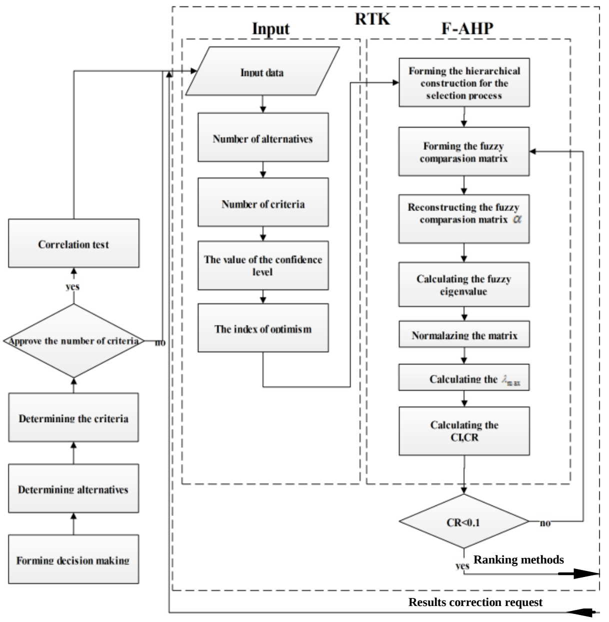


Fig. 3 *Algorithm for obtaining the relative weights of criteria*

3 IDENTIFICATION OF FACTORS THAT INFLUENCE THE SELECTION OF LOCATION

The defining of potential locations was based on consideration of the data of foreign trade exchange of Serbia, i.e. the observed region (Table 1).

Table 1. Theimports ofindividual regions of Serbia (2012. in 1000 t)[7]

Customs	Equipment	Raw materials	Consumer goods	Spare parts	Other	Total
Kraljevo	9,5	127,7	122,9	0,1	0,05	260,25
Kragujevac	46,9	982,8	328,5	1,3	3,8	1363,3
Kruševac	10,9	231,9	52,1	0,4	0,3	295,6
Užice	9,8	156,3	227,4	0,2	0,1	393,8

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 (Fig.5).

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.

Fig. 4 *Potential locations for the regional logistics center [6]*

3.1Identification and evaluation ofselection 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 2 and 3).

Table 2. Key factors for locating the logistics center[6]

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%

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 3. Key subcriteria for locating the logistics center[6]

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.

3.2.Determination of criteria relative weights

The application of described methodology of determining the relative weights was performed using the software tool developed for this purpose (Fig.5)[7]. 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 (Fig. 6) and the consistency ratio.

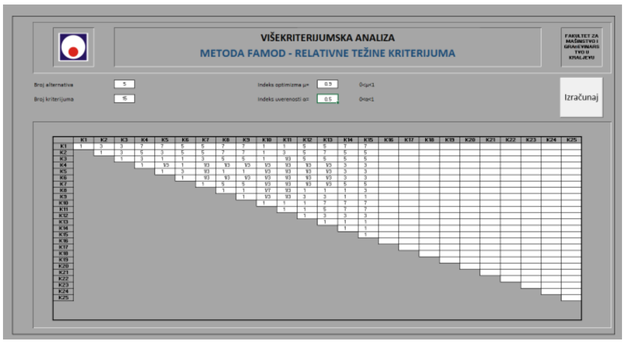


***Fig. 5** User interface of RTK program [7]*

Table 4. The fuzzy matrix of comparation

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19	K20
K1	$\tilde{1}$	$\tilde{1}$	$\tilde{5}$	$\tilde{7}$	$\tilde{7}$	$\tilde{5}$	$\tilde{5}$	$\tilde{7}$	$\tilde{5}$	$\tilde{5}$	$\tilde{7}$	$\tilde{7}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{9}$	$\tilde{9}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
K2		$\tilde{1}$	$\tilde{5}$	$\tilde{7}$	$\tilde{7}$	$\tilde{5}$	$\tilde{5}$	$\tilde{7}$	$\tilde{5}$	$\tilde{5}$	$\tilde{7}$	$\tilde{7}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{9}$	$\tilde{9}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
K3			$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
K4				$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K5					$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
K6						$\tilde{1}$	$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{7}$	$\tilde{7}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
K7							$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{7}$	$\tilde{7}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
K8								$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K9									$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K10										$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K11											$\tilde{1}$	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K12												$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K13													$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{7}$	$\tilde{7}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$
K14														$\tilde{1}$	$\tilde{1}$	$\tilde{7}$	$\tilde{7}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$
K15															$\tilde{1}$	$\tilde{7}$	$\tilde{7}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$
K16																$\tilde{1}$	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K17																	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
K18																		$\tilde{1}$	$\tilde{1}$	$\tilde{1}$
K19																			$\tilde{1}$	$\tilde{1}$
K20																				$\tilde{1}$

Table 5.α-cutmatrixfor the observed problem (criterion K1-K10)

Criterion	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1	1	1.25	5	7	7	5	5	7	5	5
K2	0.875	1	5	7	7	5	5	7	5	5
K3	0.204167	0.204167	1	3	1.25	0.354167	0.354167	3	3	3
K4	0.144345	0.144345	0.354167	1	0.354167	0.204167	0.204167	1.25	1.25	1.25
K5	0.144345	0.144345	0.875	3	1	0.354167	0.354167	3	3	3
K6	0.204167	0.204167	3	5	3	1	1.25	5	3	3
K7	0.204167	0.204167	3	5	3	0.875	1	5	3	3
K8	0.144345	0.144345	0.354167	0.875	0.354167	0.204167	0.204167	1	1.25	1.25
K9	0.204167	0.204167	0.354167	0.875	0.354167	0.354167	0.354167	0.875	1	1.25
K10	0.204167	0.204167	0.354167	0.875	0.354167	0.354167	0.354167	0.875	0.875	1
K11	0.144345	0.144345	0.204167	0.354167	0.204167	0.144345	0.144345	0.354167	0.354167	0.354167
K12	0.144345	0.144345	0.204167	0.354167	0.204167	0.144345	0.144345	0.354167	0.354167	0.354167
K13	0.354167	0.354167	3	5	3	3	3	5	5	5
K14	0.354167	0.354167	5	5	3	3	3	5	5	5
K15	0.354167	0.354167	5	5	3	3	3	5	5	5
K16	0.111806	0.111806	0.354167	0.354167	0.354167	0.204167	0.204167	0.354167	0.354167	0.354167
K17	0.111806	0.111806	0.354167	0.354167	0.354167	0.204167	0.204167	0.354167	0.354167	0.354167
K18	0.354167	0.354167	3	5	3	3	3	5	5	5
K19	0.354167	0.354167	3	5	3	3	3	5	5	5
K20	0.354167	0.354167	3	5	3	3	3	5	5	5

Table 6.α-cutmatrixfor the observed problem (criterion K11-K20)

Criterion	K11	K12	K13	K14	K15	K16	K17	K18	K19	K20
K1	7	7	3	3	3	9	9	3	3	3
K2	7	7	3	3	3	9	9	3	3	3
K3	5	5	0.354167	0.204167	0.204167	3	3	0.354167	0.354167	0.354167
K4	3	3	0.204167	0.204167	0.204167	3	3	0.204167	0.204167	0.204167
K5	5	5	0.354167	0.354167	0.354167	3	3	0.354167	0.354167	0.354167
K6	7	7	0.354167	0.354167	0.354167	5	5	0.354167	0.354167	0.354167
K7	7	7	0.354167	0.354167	0.354167	5	5	0.354167	0.354167	0.354167
K8	3	3	0.204167	0.204167	0.204167	3	3	0.204167	0.204167	0.204167
K9	3	3	0.204167	0.204167	0.204167	3	3	0.204167	0.204167	0.204167
K10	3	3	0.204167	0.204167	0.204167	3	3	0.204167	0.204167	0.204167
K11	1	1.25	0.204167	0.204167	0.204167	1.25	1.25	0.204167	0.204167	0.204167
K12	0.875	1	0.204167	0.204167	0.204167	1.25	1.25	0.204167	0.204167	0.204167
K13	5	5	1	1.25	1.25	7	7	1.25	1.25	1.25
K14	5	5	0.875	1	1.25	7	7	1.25	1.25	1.25
K15	5	5	0.875	0.875	1	7	7	1.25	1.25	1.25
K16	0.875	0.875	0.144345	0.144345	0.144345	1	1.25	0.204167	0.204167	0.204167
K17	0.875	0.875	0.144345	0.144345	0.144345	0.875	1	0.204167	0.204167	0.204167
K18	5	5	0.875	0.875	0.875	5	5	1	1.25	1.25
K19	5	5	0.875	0.875	0.875	5	5	0.875	1	1.25
K20	5	5	0.875	0.875	0.875	5	5	0.875	0.875	1

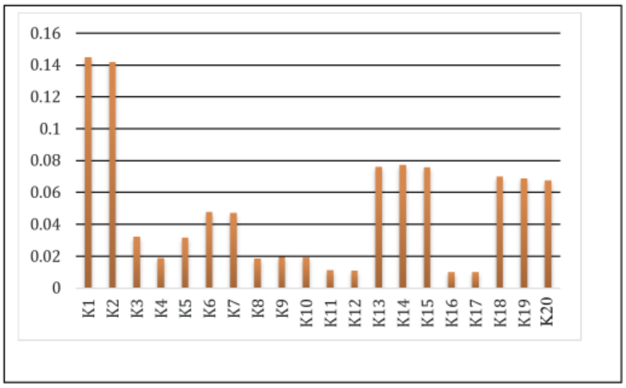


***Figure 7.** Relative weights of criteria*

Table 7. 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.

3.3.A comparative analysis of the results of multicriteria analysis methods

At this stage, predefined alternatives are evaluated on the basis of the adopted criteria and their relative weights. In order to confirm the results obtained by proposed approach as well as to prove itsapplicability and practicability, the problem is analyzed using standard and modified methods for multicriteria analysis (Fuzzy-AHPapproach, family of PROMETHEE methods and FAMOD[7]).In the observed numerical example, the decision-maker, from macro level of observing the selection of location (Fig.8), 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.

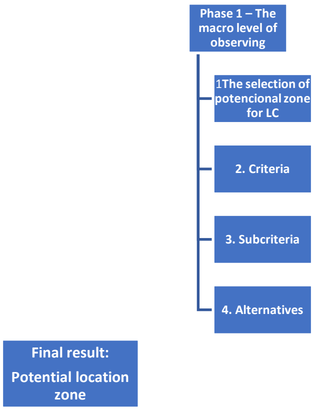
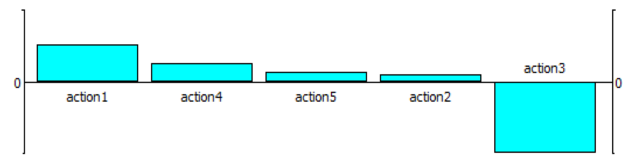


Fig. 8. *The macro level of observing*

The obtained results are shown in Table 7 and Fig. 9 and 10.

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

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



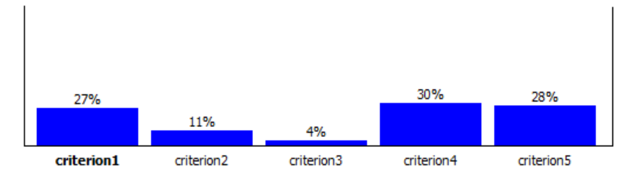
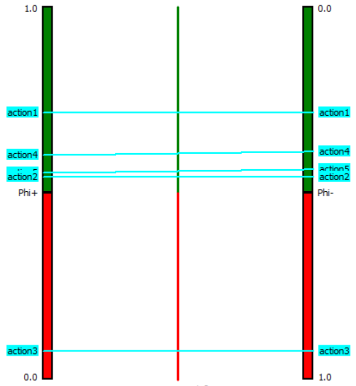


Fig. 9. *Final ranking of alternatives (FAMOD)*



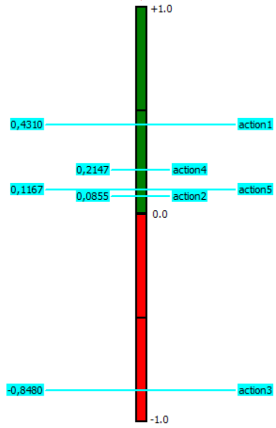


Fig. 10. *Final ranking of alternatives(PROMETHEE I, PROMETHEE II (Visual PROMETHEE Academic)*

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% and +25% do not lead to changes in the final rank of alternatives, but the change in value of -10% and -25% causes the two alternatives (A3 and A4) 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		Combined approach
	25%	10%	10%	25%	FAMOD
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

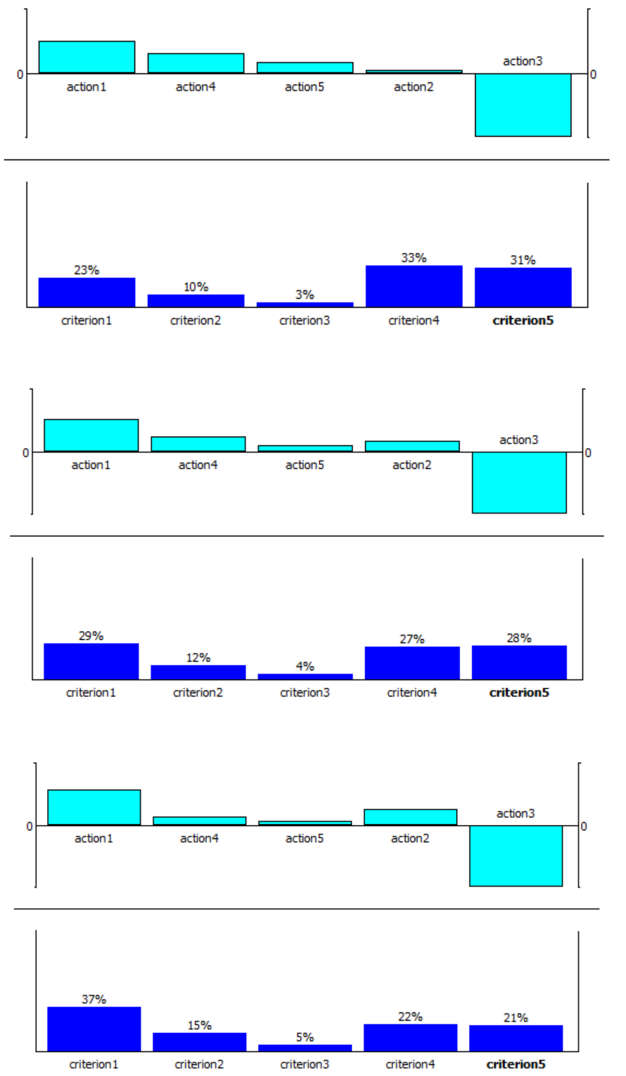


***Fig. 11**. Finalrankingofalternatives bychangingofrelativeweightsincrements -25%, -10%, + 10% and + 25%*

4 CONCLUSION

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 and to show their influence on the final results. The specificity of the above approach is 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.

Also, the fact was pointed out that a unique set of criteria of considered problem most often is not available to decision-maker. Correlation test could be usedfor getting a set of independent criteria, more precisely reduction of their number to operative and acceptable level for determining the relative weights and later on the procedure of ranking the alternatives.

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