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THE SELECTION OF THE LOGISTICS CENTER LOCATION USING AHP METHOD

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Abstract: *The aim of this paper is selection of the most acceptable location throughout the state of facts: the ability to prove the purpose of this geographical area to form one complete and complex logistics system where the logistics center (LC) would be an interconnection between production and consumption. The multi-criteria analysis, i.e. AHP method (Analytic Hierarchy Process) was used for the choice of location. Apart from the hand calculation, the "Expert Choice" software was used for better presentation of results, as well as for their validity. Based on a set of criteria and their evaluation, then the evaluation of alternatives according to these criteria, the application of the AHP method leads to the most acceptable solution.*

Keywords: *logistics center, AHP method, location, multi-criteria analysis.*

1. INTRODUCTION

The theme of this work is chosen in accordance to the needs of the economic system of a country, and the needs of all participants in that system because, as the Germans say: "Logistics is like fuel to every economic system" and it is common knowledge that logistics centers are a key element of the entire logistics network. The functioning of the entire logistics system depends on the existence of logistics centers, which have, so to speak, the role of an "umbilical cord" in logistics, since they connect and integrate all logistics systems, subsystems, activities and processes.

German agricultural economists J. H. Thun and A. Weber are considered to be the pioneers of the development of location theory, while in terms of mathematical formulations it is believed that Ferma began the consideration of location problems. Vidović and Miljuš (2004).

From methodological point of view, a multi-criteria analysis is a systematic approach, and thus the most effective and most functional methodological approach to problem solving. Since this is a multi-criteria problem, systematic approach to its solution requires the use of methods of multi-criteria analysis to optimize the solution of the identified problem. Kovačic (2008).

AHP is especially suitable for complex decisions which involve the comparison of decision elements which are difficult to quantify. It is based on the assumption that when faced with a complex decision the natural human reaction is to cluster the decision elements according to their common characteristics. It involves building a hierarchy of decision elements and then

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making comparisons between each possible pair in each cluster. This gives a weighting for each element within a cluster and also a consistency ratio. Saaty (1980)

AHP is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales. Saaty (2008)

AHP is used extensively for decision making in the areas of management, allocation and distribution. Konstantinos (2014)

2. THE PROBLEM POSTULATE AND THE METHODOLOGY

According to Zečević (2006) development of a network of LC at national and international level is a prerequisite for optimization of transport and logistics chains. The ideal solution would be the formation of the network, where all three sites under consideration had logistics center, however, the paper discusses the selection of the most acceptable solution out of a given criteria set, because in the beginning it is very important thing to have it, if only one logistics center.

Application of a multi-criteria analysis method in solving location problems is very common and there are a number of works dealing with this issue, for example solving site selection, where more methods were applied, out of which one is the AHP, as in Yildirim and Önder (2014). AHP stands out as one of the main methods of MCDM (multiple criteria decision making), when it comes to solving approach to these problems as evidenced by Tomić et al. (2014). More recently the increasingly extended AHP method is being used, ie. fuzzy AHP whose application is solving the problems of logistics nature such as in Kayikci (2010) and Tadic et al. (2015).

The choice of the logistics center location is based on an integrated decisions and risk methodology for the selection of the best locations which involves general steps as listed below: the initial step forms a schedules collection and acceptable spatial alternatives. Step 1 defines a set of criteria for decision making, step 2 identifies the initial weight of the relevant criteria, step 3 uses the AHP as one of the techniques (MCDM), step 4 establishes a ranking list of alternatives.

One of the most relevant part of the AHP, is related with to give a structure to the problem to be solve through the hierarchy. In this phase, the decision group involved should divide the problem on his fundamental components. (Saaty 1980)

AHP consists of four steps. One, define the problem and state the goal. Two, define the criteria that influence the goal. Three, use paired comparisons of each factor with respect to each other that forms a comparison matrix with calculated weights, ranked eigenvalues, and consistency measures. Four, synthesize the ranks of alternatives until the final choice is made. Melvin (2012)

Theoretically the AHP is based on four axioms given by Saaty; these are: Axiom 1: The decision-maker can provide paired comparisons aij of two alternatives i and j corresponding to a criterion/sub-criterion on a ratio scale which is reciprocal, i.e. aji=1/aij. Axiom 2: The decision-maker never judges one alternative to be infinitely better than another corresponding to a criterion, i.e. aij ≠∞. Axiom 3: The decision problem can be formulated as a hierarchy. Axiom 4: All criteria/sub-criteria which have some impact on the given problem, and all the relevant alternatives, are represented in the hierarchy in one go.

2.1. Relevant criteria

There is a number of criteria that can be studied in relation to the choice or ranking of alternatives. In order to define the relevant criteria, hierarchical structures were established, defining the group of high-level and lower-level criteria. The hierarchical structure of criteria used in this research for the choice of logistics center's location consists of 3 group criteria and 6 criteria (table 1). Criteria were chosen in accordance with the standards for defining a set of criteria to be used in solving these problems.

Table 1. The hierarchical structure of the relevant criteria

Group criteria	Criteria Level	Type
Spatial	available surface	Numerical
	Land price	
Geographic	geographical location	Linguistic
	macro-micro level of location	
Traffic	affiliation to the form of transportation	Numerical
	approach ways accessibility of transport equipment to the logistics center	Linguistic

2.2. The initial mass of relevant criteria

One of the main features of multi-criteria decision-making is that the each criteria may not have the same importance. To avoid subjectivity in the process of determining the relative weights, the criteria standardization is for the purposes of this paper, carried out by Delphi method Linstone (1975) used to identify the initial weight of the relevant criteria. The procedure for determining the initial weight was carried out in three phases, as defined by the hierarchical structure of criteria: determining the relative weight of every criteria group (g_k, $k=1..3$), determining the relative weight of every relevant criterion (c_i, $i=1..6$), corrections of relative weight of criterion with its group weight (w^i_i, $i=1..6$).

The Delphi method is based on structural surveys and makes use of the intuitive available information of the participants, who are mainly experts. Therefore, it delivers qualitative as well as quantitative results and has beneath its explorative, predictive even normative elements. There is not the one Delphi methodology but the applications are diverse. There is agreement that Delphi is an expert survey in two or more 'rounds' in which in the second and later rounds of the survey the results of the previous round are given as feedback. Therefore, the experts answer from the second round on under the influence of their colleagues' opinions. Thus, the Delphi method is a 'relatively strongly structured group communication process, in which matters, on which naturally unsure and incomplete knowledge is available, are judged upon by experts'. Häder and Häder (1995)

This research included traffic engineers, construction engineers and spatial planners, which determined criteria weighting through a survey: w_1=0.181; w_2=0.421; w_3=0.227; w_4=0.080; w_5=0.050; w_6=0.040.

3. THE SELECTION OF THE LOGISTICS CENTER LOCATION

This paper took into consideration three alternative sites: Doboj, Banja Luka and Šamac as areas that with their characteristics and geographic position are suitable places for the formation of a logistics center. Given locations are part of total number of locations, which were discussed in the study of intermodal transport for Bosnia and Herzegovina in 2008. Defined criteria are of course common to all three locations in order to make their comparison. The research represent only illustration of applying AHP method on an arbitrary set of locations for given criteria set. Hierarchical postulate of AHP method for given location problem is shown in Figure 1.

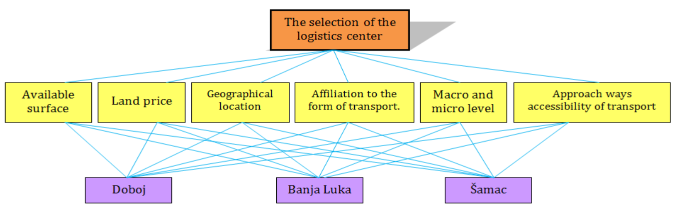

Figure 1. Hierarchical postulate of AHP method for given location problem

Comparison of alternatives in relation to the criteria on the basis of Saati 's scale Saaty (1980) is shown in table 2 where you can see their importance. For example, relation A2→A1 for K1 = 1/3 means that alternative one has low dominance compared to other alternative in relation to the first criterion.

Table 2. Comparison of alternatives per criterions

	K_1			K_2			K_3			K_4			K_5			K_6		
	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
A_1	1	3	1/5	1	7	2	1	3	4	1	1	1/9	1	4	3	1	1/3	1/3
A_2	1/3	1	1/7	1/7	1	1/5	1/3	1	3	1	1	1/9	1/4	1	1/3	3	1	2
A_3	5	7	1	1/2	5	1	1/4	1/3	1	9	9	1	1/3	3	1	3	1/2	1

In the next step a table is formed that represents the vector of eigen values of comparing alternatives with respect to the first criterion, (table 3), which is prepared as follows: a_{11}=1/(1+0.33+5)=1/6.33=0.158; a_{12}= 3/(3+1+7)=3/11=0.273; a_{13}=0.2/1.343=0.149 etc.

Table 3. Vector of own value comparison of alternatives in relation to the first criterion

	A_1	A_2	A_3	Σ
A_1	0.158	0.273	0.149	0.58
A_2	0.052	0.091	0.106	0.249
A_3	0.79	0.636	0.745	2.171

Table ΣK represents the sum of vectors of own values and in order to commence lines normalization, sum is being divided with number of columns ie. in this case with three (since we have three alternatives):

$$\frac{1}{3}\begin{bmatrix}0.58\\0.294\\2.171\end{bmatrix}=\begin{bmatrix}0.193\\0.083\\0.724\end{bmatrix};\begin{bmatrix}1&3&0.2\\0.33&1&0.143\\5&7&1\end{bmatrix}x\begin{bmatrix}0.193\\0.083\\0.724\end{bmatrix}=\begin{bmatrix}0.587\\0.25\\2.27\end{bmatrix};\begin{bmatrix}0.587/0.193\\0.25/0.083\\2.27/0.724\end{bmatrix}=\begin{bmatrix}3.041\\3.012\\3.135\end{bmatrix}$$

To calculate the maximal mean value of comparisons' matrix λ_{max}, matrix is to be multiplied with vector of comparisons, what was represented by the last matrix.

$$\lambda_{max}=\frac{1}{n}\sum\lambda_i=\frac{3.041+3.012+3.135}{3}=3.063;\ C_I=\frac{\lambda_{max}-n}{n-1}=\frac{3.063-3}{3-1}=0.0315$$

$$C_R=\frac{C_I}{R_I}=\frac{0.0315}{0.58}=0.054$$

R_I (random index) is taken from Saaty table (1980) on the base of number n which represents the alternative. Here we have three alternatives, ie. n=3 and random index value is 0.58. Here it is very important to mention that consistency degree C_R is 0.054 what means that the result is valid, because results are valid if this degree is smaller than 0.10.

When it comes to the first criterion, i.e. the available area for the location of the logistics center, the greatest significance has the number three alternative, ie. Šamac location because it has an area of about 40 ha, while second alternative has about 6 ha and the first alternative has about 10 ha, and so they are evaluated by the size of their fields. The method of evaluation of alternatives in relation to other criteria is the same and the results are given below.

If comparing of alternatives is done by the second criterion ie. the land price, the cheapest one is location number one followed by third location and at the end the second one. Such a sequence of results is a consequence of the position of locations themselves ie. location number two (Banja Luka) as the capital of the Republic of Srpska has, of course, the most expensive land as the result of a slightly higher standard than the rest of the entity. When it comes to location number three the land price is more expensive slightly compared to the price of the land at location number one, primarily because it is a land along the Sava River. When it comes to the third criterion, alternative one has the best result and that is primarily because of crossing roads - road and railway. Affiliation to the form of transportation is the fourth criterion of a given location problem, and an alternative number three has the highest priority vector according to this criterion because of the location of the port of Šamac, which has affiliation to the three aspects of transport: road, rail and waterways, while the remaining two sites only have the road and rail transport. In relation to the fifth criterion location number one has the highest priority vector because it's basically a site that has such geographical location that can serve with great success in both, micro and macro environment.

After previously completed steps, result is obtained by multiplying vectors priorities obtained by mutual comparison of criteria with alternative priority vectors according to the criteria and summing up their multiplication products.

$A_1 = WK_1 * WA_1 + WK_2 * WA_1 + WK_3 * WA_1 + WK_4 * WA_1 + WK_5 * WA_1 + WK_6 * WA_1 = \underline{\mathbf{0.467}}$
$A_2 = WK_1 * WA_2 + WK_2 * WA_2 + WK_3 * WA_2 + WK_4 * WA_2 + WK_5 * WA_2 + WK_6 * WA_2 = 0.142$
$A_3 = WK_1 * WA_3 + WK_2 * WA_3 + WK_3 * WA_3 + WK_4 * WA_3 + WK_5 * WA_3 + WK_6 * WA_3 = 0.391$

Based on commenced comparison of all input data, location number one was selected. Check of methodology was commenced with assistance of software package „Expert Choice", and result is shown in Figure 2. It is obvious that the alternative number one ie. location Doboj has the biggest priority vector, when observed generally and in total in relation with all commenced comparisons, as well as in basic postulate.

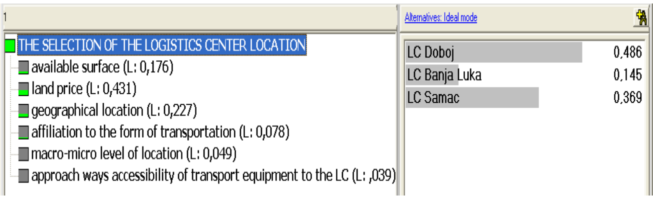

Figure 2. Final result of location selection

4. SENSIVITY ANALYSIS

The software also provides certain charts which are enabling us to perceive differences between evaluated solutions. Figure 3 makes it possible to see how the priorities of alternatives are sensitive to the weight changes of individual criteria. Increase in the weight of the second criteria (price of land - the most influential of all) causes growing of priority of the alternative number one ie. location Doboj, while priority of the remaining two locations decreases.

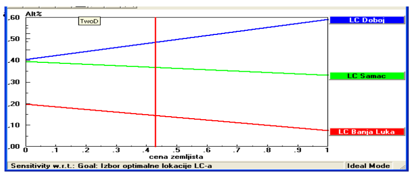

Figure 3. Gradient diagram

Figure 4. a) shows the criteria by which one alternative is preferred over the other. Selected alternatives are one and three because they have the highest priority vectors by all criteria. For instance Šamac location has the advantage when it comes to available land, belonging to the form of transport and accessibility approach of TS, while Doboj location supersedes other criteria and in the end, an overall advantage was given and highlighted in gray.

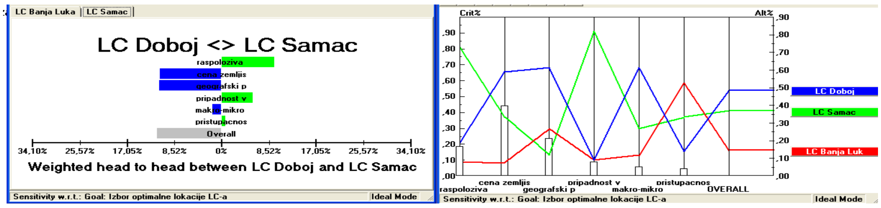

Figure 4. a) Differences diagram b) Performance diagram

Figure 4. b) shows values of alternatives per each criterion ie. per priority vector of alternatives by a single criterion. The variation of alternatives according to the criteria is clearly visible.

5. CONCLUSION

Data available during the development and the implementation of AHP as the multi-criteria analysis method, leads to solution which represents the most acceptable solution of criteria sets for the construction of the LC. It is the alternative number one in the applied method ie. location of Doboj that showed as the most acceptable for the construction of the logistics network's key element, ie. LC. Doboj as a potential location for the construction of LC has been recognized at the time of the former Yugoslavia when the top experts have made projects of LC in the territory of former republics, and among them Doboj had found its place. Then, ten years later project was re-made for the same location, which means that it is justified to construct the LC in this very much urban area.

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