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MULTI CRITERIA DECISION MAKING FOR DISTRIBUTION CENTER LOCATION SELECTION- SERBIA CASE STUDY

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Abstract: *The process of location selection for distribution center can be analyzed as a multi-criteria decision problem and has a strategic importance for many retail companies. The conventional methods for facility location selection are inadequate for dealing with the imprecise or linguistic nature of assessments and measurements. To overcome this difficulty and allow including quantitative and qualitative criteria, fuzzy multi-criteria decision-making method is proposed. The aim of this paper is to use fuzzy analytic hierarchy process (AHP) for the selection of distribution center location. The presented method has been applied to location selection problem of a retail company in Serbia. After determining the criteria that affect the facility location decisions, fuzzy AHP is applied to the problem and results are presented.*

Keywords*: distribution center, location selection, fuzzy AHP*

1. INRODUCTION

Distribution center plays a vital role in modern supply chains and it location could affect to the success, or failure of logistic company's business. It presents an organizational unit that allows differentiating between various types of stock in a site. Selecting appropriate location of distribution center is very important decision for retail firms because they are costly and difficult to reverse, and they entail a long term commitments. Decisions related to distribution center's location have an impact on operating costs and revenues. For instance, a poor choice of location might result in excessive transportation costs, a shortage of qualified labor, loss of competitive advantage, inadequate supplies of raw materials, or some similar condition that would be detrimental to operations (Stevenson 1993).

The common procedure for making decision about the best location usually consists of the following steps (Stevenson 1993): 1) Decide on the criteria that will be used to evaluate location alternatives; 2) Identify criteria that are important; 3) Develop location alternatives; 4) Evaluate the alternatives and make a selection.

There are many criteria that influence the location decisions of a distribution center. In our paper, we take into account six groups of criteria based on expert opinion and literature review, qualitative and quantitative. These are: capital (investment) costs, transportation costs, operating costs, strategic factors, supply chain and logistics factors and other factors (social, demographical, geographical, and political). Each of those criteria has their own subcriteria, and

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in total we consider 24 factors. These criteria are used to choose the best location among four alternatives (Novi Sad, Šimanovci, Novi Beograd, and Niš).

As can be seen from relevant literature, the conventional methods for facility location selection are inadequate for dealing with the imprecise or linguistic nature of criteria and analyzed factors. To overcome this difficulty and allow including variety of criteria, fuzzy multi-criteria decision-making method is proposed. In this paper we use fuzzy AHP, where the ratings of various alternative locations under various subjective criteria and the weights of all criteria are represented by fuzzy numbers.

The rest of this paper is organized as follows. Brief literature review is given in Section 2. Then in Section 3, fuzzy AHP approach is introduced. A numerical example is given in Section 4 to illustrate the proposed method. And finally, Section 5 contains concluding remarks.

2. BRIEF LITERATURE REVIEW

This section contains brief literature review on facility selection problem in supply chain. In a discrete facility location, the selection of the sites where new facilities are to be established is restricted to a finite set of available candidate locations. The simplest setting of such a problem is the one in which *p* facilities are to be selected to minimize the total (weighted) distances or costs for supplying customer demands. This is the so-called *p*-median problem which has attracted much attention in the literature (Daskin 1995, Drezner and Hamacher 2004, ReVelle and Eiselt 2005).

Significant literature review of facility location models in the context of supply chain management is given in paper (Melo et al. 2009). They identified basic features that such models must capture to support decision-making involved in strategic supply chain planning. In their chapter (Daskin et al. 2005) outlined the importance of facility location decisions in supply chain design. Ertugrul and Karakasoglu, 2008 presented fuzzy AHP and fuzzy TOPSIS methods for a facility location selection problem of a textile company in Turkey. The authors of paper (Kuoaet al. 2002) developed a decision support system for locating a new convenience store. A feedforward neural network with error back-propagation learning algorithm was applied to study the relationship between the factors and the store performance. Kahraman et al. 2003 solved facility location problems using different solution approaches of fuzzy multi-attribute group decision-making. The paper (Meng et al. 2009) addressed a novel competitive facility location problem about a firm that intends to enter an existing decentralized supply chain comprised of three tiers of players with competition: manufacturers, retailers and consumers. The paper (Özcan et al. 2011) considered AHP, TOPSIS, ELECTRE and Grey Theory applied on the warehouse selection problem.

3. BASIC ASSUMPTIONS OF FUZZY AHP

The Analytic Hierarchy Process is well known multi-criteria decision making approach introduced by Thomas Saaty (Saaty 1994).Some specifics of this approach are: the hierarchical structure of a system (goal, criteria, alternatives); the elements of one level should be compared with each other based on the elements of higher level; generating the pairwise comparison matrices; Saaty scale is used for defining the relative importance of the elements; the ability for verification of the experts' consistency; etc. Here are the specifics of applied fuzzy AHP approach.

Step 1: Define a goal, criteria, subcriteria and alternatives. Then, the importance of one criterion to the other based on the goal, subcriteria to the other based on criterion which they belong to, and finally, the importance of one alternative to the other based on each subcriterion separately. After the pairwise comparison matrices are developed, consistency validated (with eventual adjustment of importance), the alternatives rank can be determined. For comparison between these elements, the Saaty scale is used (Table 1).

Table 1. Saaty scale

Crisp value	Importance	Fuzzy value	Reciprocal crisp value	Fuzzy reciprocal value
1	Equal	(1,1,1)	1/1	(1,1,1)
2	Intermediate values	(1,2,4)	1/2	(1/4,1/2,1)
3	Weak	(1,3,5)	1/3	(1/5,1/3,1)
4	Intermediate values	(2,4,6)	1/4	(1/6,1/4,1/2)
5	Strong	(3,5,7)	1/5	(1/7,1/5,1/3)
6	Intermediate values	(4,6,8)	1/6	(1/8,1/6,1/4)
7	Demonstrated	(5,7,9)	1/7	(1/9,1/7,1/5)
8	Intermediate values	(6,8,10)	1/8	(1/10,1/8,1/6)
9	Absolute	(7,9,11)	1/9	(1/11,1/9,1/7)

With the aim to present the basic equations for application of the fuzzy AHP approach, here will be consider the fuzzy matrix **R**. The element of this matrix is fuzzy triangle number a_{ij}=(a_{ijl}, a_{ijm}, a_{ijr}) and shows a preference of one element to the other (i=1,2,..q, j=1,2,..q, where q is the number of criteria). Let us assume that this matrix **R** is the pairwise comparison of criteria, based on the goal of a model.

$$\boldsymbol{R}=\begin{bmatrix} (1,1,1) & (a_{12l},a_{12m},a_{12r}) & \cdots & (a_{1ql},a_{1qm},a_{1qr}) \\ (\frac{1}{a_{12r}},\frac{1}{a_{12m}},\frac{1}{a_{12l}}) & (1,1,1) & & (a_{2ql},a_{2qm},a_{2qr}) \\ \vdots & \ddots & \ddots & \vdots \\ (\frac{1}{a_{1qr}},\frac{1}{a_{1qm}},\frac{1}{a_{1ql}}) & \cdots & \cdots & (1,1,1) \end{bmatrix}$$

Step 2: Overall weight of elements, criteria, based on matrix **R** is calculated by following equations (Jie et al. 2006):

$$c_1=\sum_{i=1}^{q}\sum_{j=1}^{q}a_{ijl},\quad c_2=\sum_{i=1}^{q}\sum_{j=1}^{q}a_{ijm},\quad c_3=\sum_{i=1}^{q}\sum_{j=1}^{q}a_{ijr} \tag{1}$$

$$d_1=\sum_{j=1}^{q}a_{ijl,}\ d_2=\sum_{j=1}^{q}a_{ijm,}\ d_3=\sum_{j=1}^{q}a_{ijr} \tag{2}$$

$$z_{it}=\frac{d_t}{c_4-t},t=1,2,3;\ i=1,2,\ldots,q \tag{3}$$

Where: c_1, c_2, c_3 are the sum of all left, middle and right values of fuzzy triangle number a_{ij}, respectively; a_{ijl}, a_{ijm}, a_{ijr} are left, middle and right value of fuzzy number a_{ij}, respectively; d_1, d_2, d_3 are the sum by columns of all left, middle and right values of fuzzy matrix **R**, respectively, z_i is the overall weight of criteria i, and z_{i1}, z_{i2}, z_{i3} are left, middle and right value of z_i, respectively.

Step 3: Based on certain equations (Jie et al. 2006), the matrix of weighted performance of each alternative, P with fuzzy elements p_k, is defined (k=1,2..,n, where n is the number of alternatives). Thence, the matrix of total weighted performance, **S** with fuzzy elements s_k, is obtained by following relation:

$$s_k=\sum_{k=1}^{n}p_k \tag{4}$$

Step 4: Defuzzification is a procedure of choosing a particular output value. The matrix of total weighted performance, **S**, is obtained by equation (4). A variable is defined by fuzzy set which have to be transformed into crisp value. The process of transformation of fuzzy number $\sim s=(s_l, s_m, s_r)$ into crisp number is presented below (Lious and Wang 1992).

$$s = \lambda * [\alpha * (s_m - s_l) + s_m] + (1-\lambda) * [s_r - \alpha * (s_r - s_m)], \text{ where } \lambda, \alpha = [0,1] \quad (5)$$

Where λ and α are the preferences and risk tolerance of decision makers, respectively. The pessimism and optimism of decision makers can be expressed by these values.

4. FUZZY AHP FOR DISTRIBUTION CENTER LOCATION SELECTION -CASE STUDY

Retailer A that operates in Serbia for over 10 years has a retail stores in dozen of major cities but not in all. Among others, cities with stores are Beograd, Niš, Čačak, Valjevo, Šabac, Zaječar, and Obrenovac. In order to support further expansion on the market, company has decided to investigate the possibility to setup a distribution center (DC) from which retail stores will be supplied. With doing so, company is looking to achieve several benefits such as being able to negotiate better conditions with suppliers (e.g. volume and logistics rebates), reduce the stock holding costs and benefit from risk pooling, increase responsiveness of supply chain, etc. Pre-selected locations for setting up a DC are: Novi Sad, Šimanovci, Novi Beograd and Niš. Each location has some advantages and disadvantages. Since locations have many different and specific attributes, experts agree that they should be all taken into consideration and that it is not possible to relay solely to quantitative criteria. In order to support such decision making, fuzzy AHP approach is selected to support it. Based on experts' opinion all relevant elements of the model are defined (Figure 1).

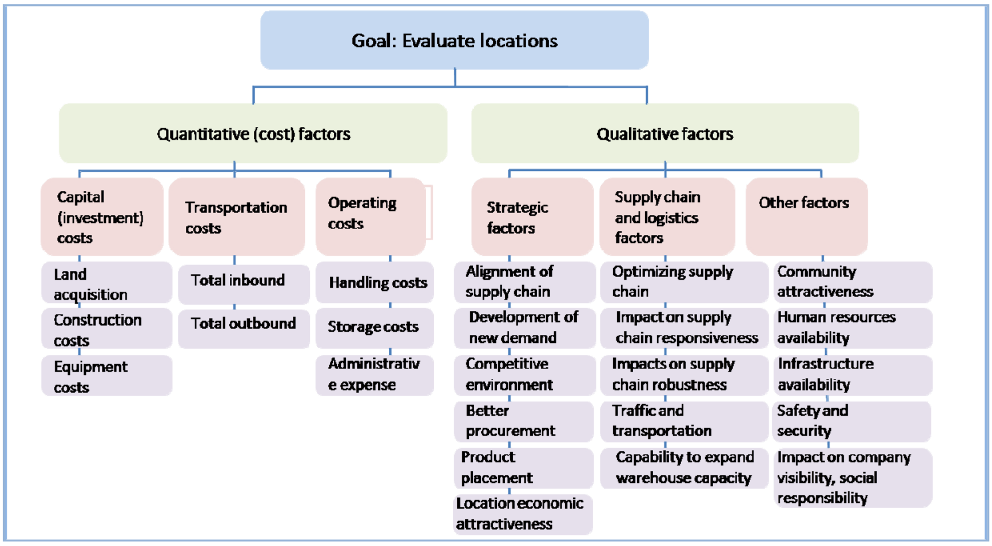

Figure 1. Quantitative and qualitative factors

4.1 Results and Discussion

After described methodology had been applied and experts had evaluated all scores, Šimanovci has shown to be the best alternative (Figure 2). This result is obtained for λ=0.5 and α=0.5. It is very closely followed by alternative-Novi Beograd, while Niš and then Novi Sad are less preferred locations although very close to each other. Speaking of criteria, experts have decided that quantitative indicators account for 2/3 of importance for making decision, and qualitative have 1/3 of importance. Figure 3 displays sorted criteria by their global weights.

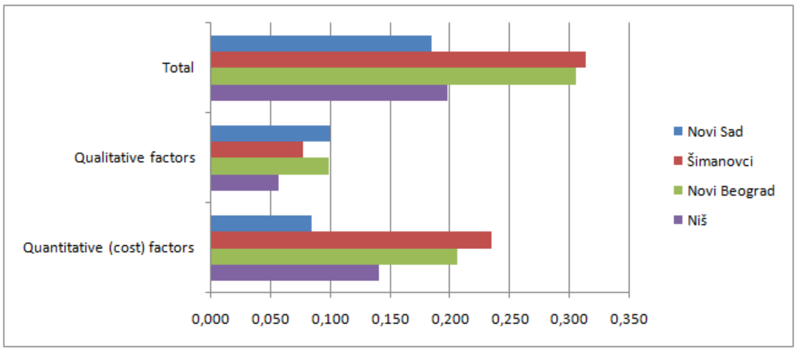

Figure 2. Final alternatives rank

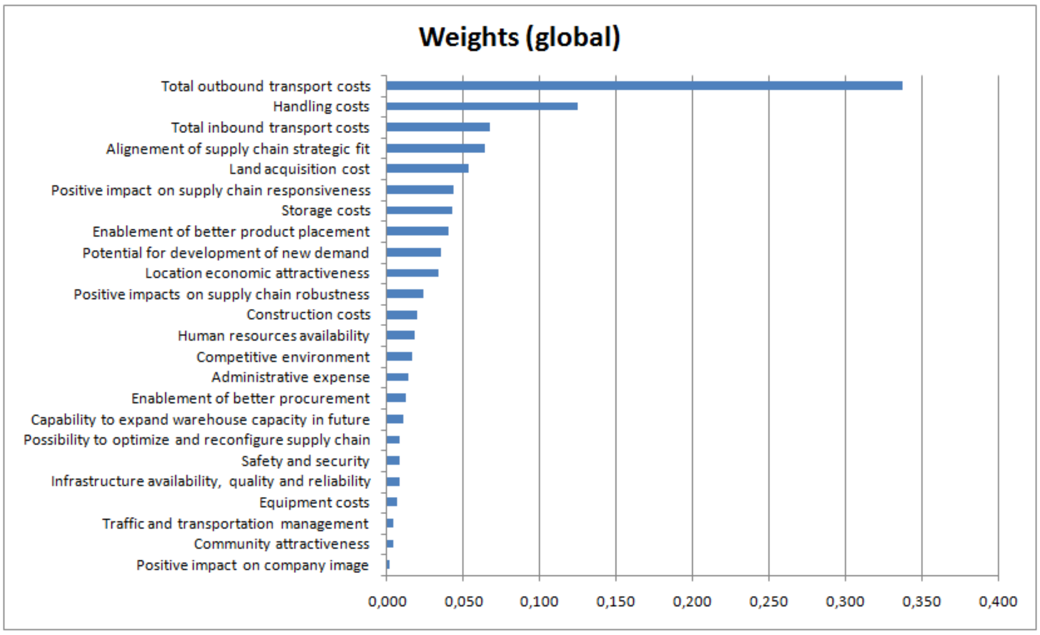

Figure 3. Final subcriteria weights

Without doubt, total outbound transportation costs are by far the most important criteria. This criteria alone accounts for 1/3 of importance for total decision. It is followed by handling costs and inbound transportation costs, so the three criteria bear together 50% of importance. Then the fourth criteria is qualitative one, which is support of location for overall supply chain strategic fit, which depends on how company wants to compete on the market, and similar to sixth ranked criteria of responsiveness improvement, thus we could say that the responsiveness of supply chain is important criteria for decision makers. Fifth is price of acquiring land, and these 6 criteria together account for 70% of importance, while the remained 30% is spread between others. Regarding the alternatives, although Novi Beograd surely optimizes the transportation costs, which is the most important criteria, but due to lower operating costs and less capital needed for investment, Šimanovci gained the overall advantage. The strategic, supply chain/logistics and other factors have very close values for both locations.

5. CONCLUSION

The model for distribution center location selection is developed in this paper. Authors suggested the fuzzy AHP for solving the proposed problem. After defining the potential locations, as alternatives, and all relevant factors in the process of selection, i.e. criteria and subcriteria, the proposed approach is applied to location selection problem of a retail company in Serbia. Finally, the best alternative compared to other four, is obtained. Proposed model selected Šimanovci as the best solution. From managers' point of view this location can decrease transportation costs, increase competitive advantages, etc. Moreover, proposed framework can help managers in making future DC location decisions, by using this intuitive and effective approach. In order to take both quantitative and qualitative factors into consideration, as well as the preference and risk tolerance (optimism/pessimism) factors, presented fuzzy AHP model gives a solid basis for analytical but practical decision making and its application.

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REFERENCES

[1] Daskin, M. (1995). Network and Discrete Location: Models, Algorithms, and Applications. Wiley, New York.

[2] Daskin, M., Snyder, L., Berger, R.(2005). Facility Location in Supply Chain Design. Chapter in: Logistics Systems: Design and Optimization. 39-65.

[3] Drezner, Z., Hamacher, H.W. (Eds.) (2004). Facility Location: Applications and Theory, Springer, New York.

[4] Ertuğrul, I., Karakaşoğlu, N.(2008). Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection. Int J Adv Manuf Technol, 39, 783–795.

[5] Jie, L.H., Meng, M.C., Cheong, C. W. (2006). Web based fuzzy multicriteria decision making tool. International Journal of the Computer, the Internet and Management, 14(2). 1-14.

[6] Kahraman, C., Ruan, D., Doğan, I.(2003). Fuzzy group decision-making for facility location selection. Information Sciences, 157, 135–153.

[7] Kuoa, R.J., Chib, S.C., Kaoc, S.(2002). A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network. Computers in Industry, 47, 199–214.

[8] Lious, TS., Wang, MJJ. (1992) Ranking fuzzy numbers with integral value. Fuzzy Sets System, 50(3), 247-255.

[9] Melo, M.T., Nickel, S., Saldanha-da-Gama, F.(2009). Facility location and supply chain management – A review. European Journal of Operational Research, 196, 401–412.

[10] Meng, Q., Huang, Y., Long, R.(2009). Competitive facility location on decentralized supply chains. European Journal of Operational Research, 196, 487–499.

[11] Özcan, T., Çelebi, N., Esnaf, S.(2011). Comparative analysis of multi-criteria decision making methodologies and implementation of a warehouse location selection problem. Expert Systems with Applications, 38. 9773‑9779.

[12] ReVelle, C.S., Eiselt, H.A.(2005). Location analysis: A synthesis and survey. European Journal of Operational Research, 165, 1–19.

[13] Saaty, Th. (1994) Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process. RWS

[14] Stevenson, W.J. (1993). Production / operations management, 4th edn. Richard D. Irwin Inc., Homewood