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THE SELECTION OF THE LOGISTICS DISTRIBUTION FRUIT CENTER LOCATION BASED ON MCDM METHODOLOGY IN SOUTHERN AND EASTERN REGION IN SERBIA

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Abstract. *Location selection for the logistics distribution center is often one of the most critical elements in a supply chain's management success. Decision making in location selection domain is a complex process due to the fact that a wide range of diverse criteria, stakeholders and possible solutions are embedded into this process. This paper focuses on the application of some multi-criteria decision-making (MCDM) approaches for the logistics distribution fruit center location selection in the Southern and Eastern Serbia region. An Analytic Hierarchy Process (AHP) and a Weighted Aggregated Sum-Product Assessment (WASPAS) have been implemented in this process for evaluation and location selection.*

Key words: *location selection problem, logistics distribution center, MCDM, AHP, WASPAS.*

1. Introduction

The location selection problem (Owen & Daskin, 1998; Farahani & Hekmatfar, 2009; Zak & Weglinski, 2014) consists in determining proper placement of an infrastructural component (ground, site, facility, etc.) in a considered area, taking into account the decision maker's preferences and existing constraints. It has a universal character and may refer to different categories of sites (Farahani & Hekmatfar, 2009; Farahani, et al, 2010; Zak & Weglinski, 2014). The location selection problem plays a crucial role in logistics, where it refers to find the most desirable location for logistics facilities.

The main goal of this paper is to show the usage of multi-criteria decision-making (MCDM) methodology on the location selection problem which refers to an installment of the logistics center for storing and distribution of fruits on the territory of Southern and Eastern region in Serbia.

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As a key component in a supply chain, the distribution center, plays the vital role of obtaining materials from different suppliers, performing value-added activities, and assembling (or sorting) products to fulfil customer orders and offer a high level of service (Baker, 2007, 2008; Parkih & Meller, 2008; Vieira et al., 2017).

To improve every aspect of the supply chain and satisfy all relevant involved factors for the most suitable logistics center location, a multi-criteria decision-making problem (MCDM) methodology has been used.

To solve problems related to decision-making, Ćojbašić et al. (2018) say that several optimization methods are used in practice. But, in the case where decision activities are based on similar options, it becomes critical to analyze various factors, alternatives with similar category, involving a set of different and opposite criteria.

When MCDM methods are applied for solving the location selection problem, they can help decision-maker with objective and systematic evaluation of alternatives on multiple criteria.

Two MCDM methods, which are applied on the practical example (the location selection of the logistics distribution center), are classical MCDM method - Analytic Hierarchy Process (AHP) method and hybrid MCDM method - Weighted Aggregated Sum Product Assessment (WASPAS) method. The first method, the AHP method, was used for the determination of the criteria weights, and, furthermore, for the evaluation of the alternatives. The second method, the WASPAS method, was only used for the evaluation of the alternatives while using the criteria weights determined by the AHP method.

The location selection of the logistics distribution fruit center is being determined inside the Southern and Eastern Serbia region (alternative solutions are region's districts with their govern cities). By the defined criteria set, alternatives are evaluated with the help of the mentioned MCDM methods (Section 4).

The final result of this paper should be, respectively to the previously emphasized distribution center importance, the best possible location for its installment. This location will be proposed to the responsible authorities of the Southern and Eastern region, as well as the Ministry of Agriculture, Forestry and Water Management.

2. The location selection problem – Literature Preview

The location selection problem is a worldwide "phenomenon", which is widely discussed in transportation and logistics circles.

This problem (Owen & Daskin, 1998; Chen, et al., 2007; Daganzo, 1996; Ozcan, et al., 2011) refers to the selection of specific locations of such facilities as: warehouses, distribution centers, transportation hubs, passenger and cargo terminals, material inventory, parking lots and many others (Van Thai & Grewal, 2005; Drezner & Hamacher, 2002; Fierek, et al, 2007; Zak & Weglinski, 2014).

The focus of this paper is location selection for the logistics distribution center and Gutjahr & Dzubur (2015) said that in the literature on facility location, much attention has been devoted to the optimal choice of facilities or distribution centers where customers are supplied with products, commodities or services of a different kind.

Logistics distribution centers have evolved from traditional warehouses. The main difference between distribution centers and warehouses is in the fact that a warehouse is designed to store goods for longer periods. Distribution centers are facilities with the primary purpose of logistic coordination. Beside manipulative activities (loading, unloading, load transfer), constantly adapting to new market demands, continuous automation and computerization, there is a development in trade, delivery and transport functions in logistics systems on all levels (Pupavac et al., 2014).

Choosing the most suitable location for the logistics distribution center is a complex decision which involves the consideration of multiple factors including: politics, economics, infrastructure, environment, competition, development strategy, product features, logistic costs, and customers service levels (Rao et al., 2015).

The complexity of the problem increases with the increase of the possible solutions and number of the criterion which affects them. Choosing the most suitable location for the logistics distribution center becomes the MCDM problem.

MCDM methods can help decision-maker with objective and systematic evaluation of possible solutions-locations, on multiple criteria involved. To find the best alternative the location selection models have been designed. Over the past decades, those models have increased significantly (Kazemi & Amiri, 2017). These models are principally mathematical models that can be categorized into two groups: static and deterministic and dynamic and stochastic (Cheng at al., 2005). But, the most recent models contain both quantitative and qualitative values with the concentration on decision-makers' behavior (Hashemkhani et al., 2013). Some classical and hybrid models are included in MCDM methodology, as presented in this research.

Multiple criteria facility location problems were presented by Farahani et al. (2010), while the study on location selection started more than a century ago when researchers were trying to find the most suitable location of the warehouse in order to have minimum distance with the customer (Cheng et al., 2005). Chou et al. (2008) utilized mathematical programming in order to process the facility model for a distribution center.

Stevic et al. (2015) and Bagum & Rashed (2014) used classical AHP method on the selection of the logistics distribution center location. The same method was used by Tomić et al. (2014) in order to find the best locations for the distributive center on the Balkan Peninsula. Burnaz et al., (2006) applied the MCDM approach for the evaluation of retail locations. Ozcan et al. (2011) proposed a comparative analysis of MCDM methods (TOPSIS, ELECTRE and Grey Theory) on a warehouse location selection problem. Selection of a similar problem was done combining AHP and DEA methodology (Korpela et al., 2007). The selection of the logistics center location based on the ELECTRE III/IV method was carried away in Poland (Zak & Weglinski, 2014). ELECTRE methods were also used by Wang & Triantaphyllou (2008) for ranking irregularities while evaluating alternatives.

Nowadays, more and more popular are fuzzy variants of MCDM methods and He et al., (2017) used fuzzy TOPSIS and fuzzy EW+AHP for sustainable decision making for joint distribution center location selection. Fuzzy optimization has been applied for locating and distributing centers in a supply chain network (Chen et al., 2007). Sanayei et al. (2010) proposed VIKOR MCDM method under the fuzzy environment in the selection process. Steep-fuzzy AHP+TOPSIS method has been developed for evaluation and selection of thermal power plant location (Choudhary et al., 2012).

3. Multi-criteria decision-making (MCDM) methods

Multi-criteria analysis methods have been developed as mathematical tools to support decision-makers involved in the decision-making process (Madić et al., 2015). Those methods are gaining importance as potential tools for analyzing and solving complex real-time problems due to their inherent ability to evaluate different alternatives concerning various criteria for possible selection of the best alternative (Chakraborty et al., 2015).

They are based on scientific principles that enable an effective and efficient way of determining the “optimal” solution. Some methods have many common features or a similar application procedure, while others are different, but most of them, are based on quantitative calculations. Each method has some of its unique characteristics, logic, advantages, and disadvantages, depending on a decision-making problem (Madić et al., 2015; Petrović et al., 2018).

The choice of the method which will be in use for solving the specific multi-criteria analysis problem depends on: the nature of the problem, the availability of information concerning a problem, the number of alternatives, as well as the knowledge, previous experience and preferences of the decision-maker.

When a particular MCDM method is finally chosen for a specific application, it is observed that its solution accuracy and ranking performance are seriously influenced by the value of its control parameter (Chakraborty et al., 2015).

Proposed MCDM methods for solving this paper’s decision-making problem, the location selection problem, are: Analytic Hierarchy Process (AHP) and Weighted Aggregated Sum-Product Assessment (WASPAS).

In order to evaluate the overall effectiveness of the candidate alternatives (locations), rank and select the most suitable location, the primary objective of an MCDM methodology is to identify the relevant location selection criteria, assess the alternatives information relating to those criteria and develop methodologies for evaluating the significance of criteria (Ćojbašić et al., 2018).

The weights of relevant location selection criteria are calculated by the AHP method, while, the same method and WASPAS method are furthermore used for evaluation of alternatives (locations).

3.1. Analytic Hierarchy Process (AHP) method

The Analytic Hierarchy Process (AHP) method was originally proposed by Thomas Saaty (1977, 1980). It represents one of the best known and the most commonly used MCDM method.

The AHP can be implemented in a few simple consecutive steps:

Step 1: Computing the vector of criteria weights. The vector of criteria weights can be computed by creating a *pairwise comparison matrix* $\boldsymbol{A}$ where each element a_{ij} of the matrix $\boldsymbol{A}$ represents the importance of the i^{th} criterion relative to the j^{th} criterion. The comparisons between two elements are assembled, using the values from 1 to 9 from fundamental Saaty scale. Final determination of criteria weights w_j is based on the geometric mean method as shown by the following equation:

$$GM_i = \left(\prod_{i=1}^{n} a_{ij}\right)^{1/n}, \; w_i = \frac{GM_i}{\sum_{i=1}^{n} GM_i}, \tag{1}$$

where GM_i is geometric means of each row and n is the number of considered criteria.

Step 2: Testing the consistency of results. The pairwise comparisons made by AHP method are subjective and this method tolerates inconsistency through the amount of redundancy in the approach. The value that measures the consistency of the subjective comparisons is *consistency index CI*:

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

where $\lambda_{\max}$ is the maximum eigenvalue of the *pairwise comparison matrix* $\boldsymbol{A}$.

Finally, the ratio CI/RI, that is termed the *consistency ratio CR,* should be less than 0.1. In Eq. 3 RI is the *Random Index* (Table 1), i.e. the consistency index when the entries of matrix $\boldsymbol{A}$ are completely random.

$$CR = \frac{CI}{RI} \tag{3}$$

Table 1. Values of a Random Index (RI) depending on the number of criteria

Number of criteria	3	4	5	6	7	8	9	10
RI	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Step 3: Comparison of alternatives concerning each criterion. This step implies the determination of pairwise alternative comparison matrix $\boldsymbol{B_j}$, where elements of this matrix b_{kl} represent the preference of the k^{th} alternative relative to the l^{th} alternative according to criterion j. The comparisons have to be done using the values from 1 to 9 from Saaty scale in the same way as described in Step 1.

Step 4: Synthesize global ratings. The final step is the multiplication of local priorities by the weight of the respective criterion and the results are summed up to produce the overall priority of each alternative (global ratings).

3.2. Weighted Aggregated Sum Product Assessment (WASPAS) method

Weighted Aggregated Sum Product Assessment (WASPAS) method was proposed by Zavadskas et al. (2012). The WASPAS method is a unique combination of two well-known MCDM approaches, i.e. Weighted Sum Model (WSM) and Weighted Product Model (WPM) (Chakraborty et al., 2015).

The WASPAS can be implemented in a few simple consecutive steps:

Step 1: Determine the decision matrix:

$$X = \left[x_{ij}\right] = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{4}$$

where x_{ij} represents the performance of i-th alternative with respect to j-th criteria; m is the number of alternatives and n is the number of the criteria.

Step 2: Determine the normalized decision matrix computing its elements by one of the formulas:

$$\bar{x}_{ij} = \frac{x_{ij}}{\max_i x_{ij}}, \text{ for maximal criterion,} \tag{5}$$

$$\bar{x}_{ij} = \frac{\min_i x_{ij}}{x_{ij}}, \text{ for minimal criterion,} \tag{6}$$

where $\bar{x}_{ij}$ is the normalized value of x_{ij}.

Step 3: The first criterion of optimality is similar to WSM method. The total relative importance of the *i*-th alternatives is determined by the formula:

$$Q_i^{(1)} = \sum_{j=1}^{n} \bar{x}_{ij} \cdot w_j , \tag{7}$$

where w_j is the weighted coefficient of the *j*-th criteria.

Step 4: The second criterion of optimality is similar to WPM method. The total relative importance of the *i*-th alternatives is determined by the formula:

$$Q_i^{(2)} = \prod_{j=1}^{n} \bar{x}_{ij}^{w_j} . \tag{8}$$

Step 5: A joint importance is based on the contribution of WSM and WPM:

$$Q_i = \frac{Q_i^{(1)} + Q_i^{(2)}}{2}. \tag{9}$$

To increase ranking accuracy and effectiveness of the decision-making process, in WASPAS method, a more generalized equation for determining the total relative importance of *i*-th alternative is developed as below (Saparauskas et al., 2011; Zavadskas et al., 2012):

$$Q_i = \lambda \cdot Q_i^{(1)} + (1-\lambda) \cdot Q_i^{(2)} = \lambda \cdot \sum_{j=1}^{n} \bar{x}_{ij} \cdot w_j + (1-\lambda) \cdot \prod_{j=1}^{n} \bar{x}_{ij}^{w_j} ,$$
$$\lambda = 0, 0.1, \ldots, 1. \tag{10}$$

Now, the candidate alternatives are ranked based on the Q values, i.e. the best alternative would be that one having the highest Q value.

4. Case study – The selection of the logistics distribution fruit center location

The Southern and Eastern Serbia is one of five statistical regions of the Republic of Serbia. This region covers the area of 26 255 km^2, which makes 29.71% out of the whole country's area. In this region live 1 559 281 citizens, this makes 21.5% out of the entire population (by the 2011 Census, Statistical Office of the Republic of Serbia).

Southern and Eastern Serbia consists of 9 districts (every district has administrative center): Bor District (Bor), Braničevo District (Požarevac), Jablanica District (Leskovac), Nišava District (Niš), Pčinja District (Vranje), Pirot District (Pirot), Podunavlje District (Smederevo), Toplica District (Prokuplje), Zaječar District (Zaječar) (Figure 1).

Alternatives (locations) are administrative centers form A_1 to A_9 respectively ordered by Districts, as in the previous passage, and shown in Figure 1 and 2, and in decision matrix in Table 2.

Figure 1. Southern and Eastern Serbia region's districts.

By the Agricultural Census from 2012 (Statistical Office of the Republic of Serbia), there are 187 744 registered agricultural holdings in the Southern and Eastern region, this makes 29.75% out of all registered agricultural holdings. 97 401 registered agricultural holdings are registered as the fruit growing holdings, on the total area of 43 372 ha.

Mentioned number of agricultural holdings grow a wide selection of fruits, such as apples, pears, peaches, apricots, plums, quinces, different sorts of nuts (walnuts, hazelnuts, almonds, etc.), as well as the berry fruits (raspberry, strawberry, blackberry, blueberry, etc.).

This paper shows the usage of MCDM methodology as a reliable tool in the decision-making process, and that the result of this process should be a proposal for construction of logistics distribution fruit center in one of the 9 Districts inside the Southern and Eastern Serbia Region. Designed logistic distribution center should be used to store fruit products, as well as their further distribution inside the region, inside the country and abroad.

The selection of the location for the logistics distribution center has become a key concern in logistics and supply chain management practice and design.

The proposed MCDM methods from Section 3 have been used for logistics distribution fruit center location evaluation and selection.

The working model for location selection of the logistics distribution fruit center in Southern and Eastern Serbia region is presented in the Figure 2.

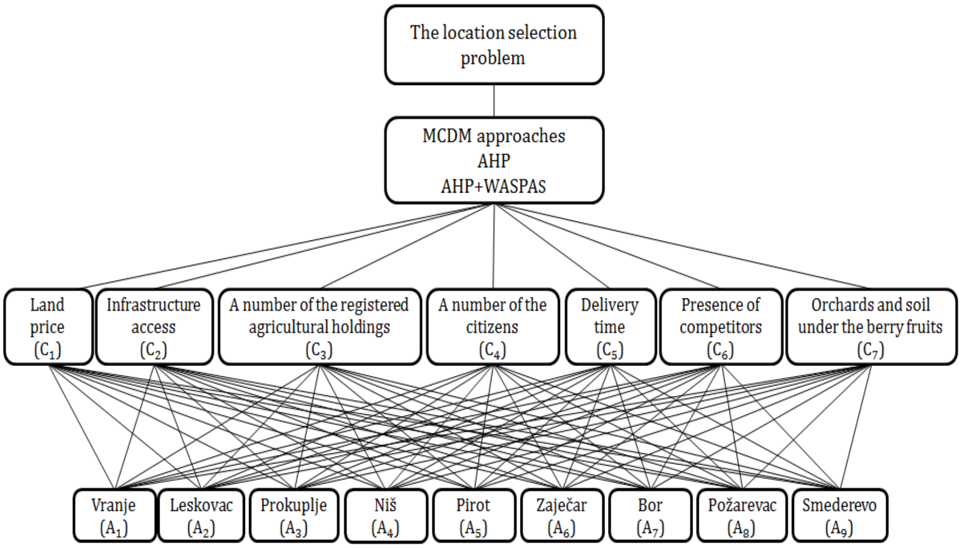

Figure 2. A model for the location selection problem.

A well-considered logistic distribution center will reduce the logistics cost, improve the efficiency of transport flows, improve a citizen's living condition, sustain the city's economic vitality and can contribute to the harmonious development of the economy, environment, and society. However, a poorly designed logistic distribution center can cause a series of negative externalities and external costs, such as greater traffic congestion, increased emission, road safety, and damaged urban image (Rao et al., 2015).

This paper's criteria set consist of 7 criterions. Those criteria have been based on the factors that affect the problem, of the location selection, the most. The criteria set have been chosen on the previous authors' experience – literature preview, type of the problem (location selection problem), as well as the current fruit growing situation in the Region.

C_1 – Land price is the minimization criterion defined on the basis of grades. Land price is a very important factor for logistics distribution center construction because it directly affects the increase of the investment costs. Besides the required amount of land which is necessary for the logistics distribution center, there must be enough additional surrounding space available for future development.

C_2 – Infrastructure access is the maximization criterion defined on the basis of grades. Transportation is the essence of logistics distribution, and logistics distribution center must have a variety of possible means of transport (highways, railroads, river ports, airports) in order to facilitate transit.

C_3 – A number of the registered agricultural holdings is also the maximization criterion which represents the total number of the agricultural holdings which are oriented in growing fruits by the District (Agricultural Census 2012, Statistical Office of the Republic of Serbia).

C_4 – A number of the citizens is the maximization criterion which represents the total number of the citizens by the District (by the 2011 Census, Statistical Office of the Republic of Serbia). The number of citizens dictates the number of customers and available label workers.

C_5 – Delivery time is the minimization criterion, and it is very important that delivery must be on time, especially, because of the product's type. This criterion is in relation to criterion C_2 – Infrastructure access, and it also depends on the delivery destination.

C_6 – Presence of competitors is the minimization criterion defined on the basis of grades. This criterion refers to the level of competitors' presence in the Districts. The less competitive environment, the better the result is.

C_7 – Orchards and soil under the berry fruits is maximization criterion which represents the total amount of soil under fruits by the District (Agricultural Census 2012, Statistical Office of the Republic of Serbia).

Criteria C_1, C_2, C_5, and C_6 are evaluated by the group of experts on the basis of the Saaty's scale for pair-wise comparison of 9 numerical values. After the evaluation of the criteria, mean values were taken into account. On the other hand, for the criteria C_3, C_4 and C_7, real values were taken.

Decision matrix has been formed and presented in Table 2 and based on the described alternatives (locations) and defined criteria.

Table 2. Location's performance ratings – decision matrix

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Alternative	min	max	Max	Max	min	Min	Max
A_1	4.8	5.0	12609	158717	5.6	7.4	3874.6
A_2	7.4	7.2	16669	216304	2.4	7.0	6819.08
A_3	4.0	4.6	12625	90600	2.4	3.6	9828.69
A_4	8.2	8.8	15400	373404	1.4	6.8	5527.7
A_5	3.0	4.4	7519	92277	2.8	6.4	1874.85
A_6	4.0	3.6	8501	119967	4.0	4.4	3603.94
A_7	2.6	4.0	4804	124992	5.8	2.6	1529.34
A_8	4.2	5.0	12461	183625	3.4	5.0	4019.88
A_9	8.4	7.4	6813	199395	2.2	7.8	6294.35

The team of experts has also evaluated the significance of the defined criteria by creating a pairwise comparison matrix (Table 3).

Table 3. Evaluation of criteria – pairwise comparison matrix

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	1.000	0.294	0.263	5.200	0.278	7.200	2.200
C_2	3.400	1.000	2.200	7.400	0.417	8.600	3.400
C_3	3.800	0.455	1.000	5.200	0.313	7.600	2.600
C_4	0.192	0.135	0.192	1.000	0.122	3.600	0.455
C_5	3.600	2.400	3.200	8.200	1.000	8.800	5.200
C_6	0.139	0.116	0.132	0.278	0.114	1.000	0.238
C_7	0.455	0.294	0.385	2.200	0.192	4.200	1.000

Table 4. Criteria weights obtained using AHP MCDM method

Criteria weights	C_1	C_2	C_3	C_4	C_5	C_6	C_7
AHP	0.113	0.234	0.171	0.039	0.354	0.021	0.068

To ensure the objectivity of the calculated criteria weights the consistency index (CR) has been calculated and its value is 0.087, while the maximal allowed value of this index is 0.1.

AHP method and hybrid combination of the MCDM method (AHP+WASPAS) were used for the complete assessment for the logistics distribution fruit center location in Southern and Eastern Serbia region. The application of the proposed methods gives a complete range of location selection, as shown in Table 5 and Figure 3.

Table 5. Complete rankings of the locations according to different MCMD approaches

Log. Distr. center location	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
AHP	0.082 (7)	0.123 (2)	0.108 (4)	0.164 (1)	0.095 (6)	0.079 (8)	0.075 (9)	0.097 (5)	0.109 (3)
AHP+WASPAS	0.443 (7)	0.671 (2)	0.615 (3)	0.842 (1)	0.487 (6)	0.425 (8)	0.371 (9)	0.528 (5)	0.584 (4)

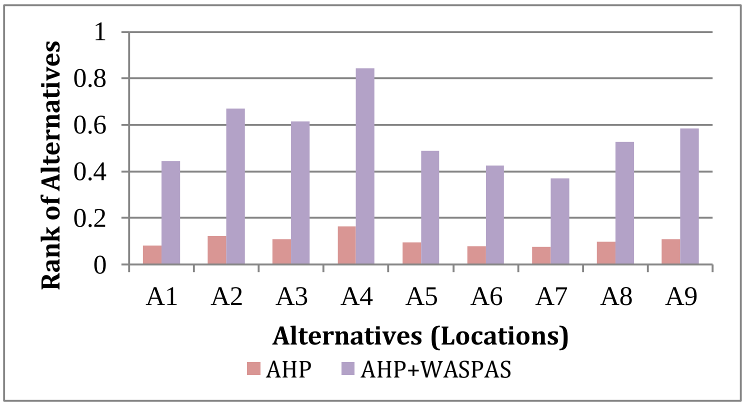

Figure 3. Complete rankings of the locations according to different MCDM approaches.

In accordance with those table and figure, it can be seen that ranks are of the same importance in both methods. In both cases (AHP and AHP+WASPAS) the best alternative solution is the alternative A_4, i.e. the best location for the logistics distribution fruit center is the administrative center, the city of Niš (Nišava District). On the other hand, in both cases too, the worst alternative solution is the alternative A_7, i.e. the worst location for the logistics distribution center is the administrative center, the city of Bor (Borski District).

The only difference in the results of those two MCDM approaches is for the alternative A_3 (Administrative Center of Prokuplje – Toplica District) and A_9 (Administrative Center of Smederevo – Podunavlje District).

In the case of classic MCDM approach (AHP method), alternative A_3 has a rank 4, while alternative A_9 has a rank 3.

In the case of hybrid MCDM approach (AHP+WASPAS), alternative A_3 has a rank 3, while alternative A_9 has a rank 4.

5. Conclusion

This research has demonstrated the applicability of classic MCDM approach (AHP method) and a hybrid MCDM approach (AHP+WASPAS) in the location selection for logistics distribution fruit center in Southern and Eastern Serbia region.

In the case of logistics center location both considered approaches give insignificant variation in the final ranking scores. Both approaches selected alternative A_3 (administrative center, the city of Niš (Nišava District)) as the best choice.

The authors of this paper belong to a narrow group of researches (e.g. Daganzo, 1996; Zak & Weglinski, 2014) who have realized that the logistics distribution center must be considered as a hierarchical problem, a two-level problem.

The first level represents a macro analysis of the one wider area, which has been described in this paper. The selection of the best location for the logistic distribution fruit center was done by observing the whole Southern and Eastern Serbia region. In the macro-region analysis potentials and advantages of the Districts was observed to construct a logistics center of this type.

The second level represents a microanalysis for described logistics center inside the previously chosen location in the first level of study. The main goal of further research is to find the best possible location (exact location) of the logistics distribution center inside the chosen District.

The most important future endeavors regarding the usage of the MCDM methodology are directed to the development of an expert and intelligent decision-making system.

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