Logistics, Supply Chain, Sustainability and Global Challenges
doi: 10.2478/jlst-2024-0003

Application of the VIKOR method for solving problems in logistics

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***Abstract* — When companies make strategic decisions, responsible persons must take into account as many influential parameters as possible so that the solution to the given problem is the most optimal, that is, they make the most appropriate decision. Multi-criteria decision-making (MCDM) can find a very large application for solving such very complex and important issues, where it is of particular importance that the company makes the most appropriate decision. Making the optimal decision for a given problem directly affects the financial performance of a given company.**

In this paper, the VIKOR method will be applied, which until now has not been used to solve problems related to the choice of warehouse location, but is very often and very successfully used to solve various complex problems when applying multi-criteria decision making (MCDM). The purpose of this paper is to show that the VIKOR method can be successfully applied to select the optimal warehouse location for a company that has subsidiaries in multiple locations.

***Index Terms* — selection, location, warehouse, multi-criteria decision making, VIKOR method**

I. INTRODUCTION

Logistics is represented in everyday life and the functioning of all systems. Logistics especially comes to the fore in the functioning of large companies, where it has a very large and significant influence in making capital decisions. One of the very important decisions for companies with several subsidiaries, i.e. dispersed locations, is the choice of the location of the main warehouse for spare parts and consumables. In some cases, when the site selection decision is made, it is optimal, but after a few years it may become suboptimal. This is a consequence of the development and application of the latest technologies, whereby there is a need to modernize warehouses in order to reduce current costs, further the need to provide a higher level of services for the competitive advantage in the market, etc.

There are several classic methodologies that are applied to choose a warehouse location (Stefanov, 2023). However, when it comes to a capital facility, which has a high cost of construction and maintenance, as well as servicing multiple locations, in that case a much deeper analysis of the problem is required. When choosing a warehouse location, it is necessary to consider several alternatives and compare them based on several criteria. In this way, a decision will be made on the optimal choice of location. Multi-criteria decision-making (MCDM) uses several criteria, so that the obtained solution is the most optimal for the given problem (Mijalkovski et al., 2023).

In addition to the selection of the location of the warehouse, other very important strategic decisions that should be made by the engineer in charge of logistics are: selection of the location of the factory, selection of means of transport, selection of auxiliary machinery (own or external, i.e. subcontractors), selection for hiring labor (own or external ie subcontractors) and a very large number of selection decisions.

Many authors have been engaged in research related to the application of MCDM for solving problems in logistics. Some of the more significant research conducted in this direction is: In 2024, Mijalkovski et al. applied the TOPSIS method (Mijalkovski et al., 2024a), and then the EDAS method for selecting the main warehouse location (Mijalkovski et al., 2024b). In 2022, Wang et al. applied a multi-criteria decision-making method to the analysis of location selection and evaluation in urban integrated power plants based on a geographic information system (Wang et al., 2022). Yousefi et al 2022 applied a multi-criteria decision-making system for wind farm location selection using a geographic information system (GIS) (Yousefi et al., 2022). In 2021, Margana et al. applied the center of gravity method for the purpose of choosing the location of a distribution center in a small and medium-sized enterprise (Margana et al., 2021). In 2021,

Article History: Received March 2024; Revised May 2024; Accepted June 2024

Shaikh et al applied multi-criteria decision-making methods to make a decision to identify an ideal business location (Shaikh et al., 2021). In 2021, Sahin applied multi-criteria decision-making methods for location selection, based on objective and subjective weights (Sahin, 2021). In 2021, Arunyanart et al. Investigated international location selection for production fragmentation (Arunyanart et al., 2021). Alkaradaghi et al. 2020 performed landfill site selection using GIS and AHP and SAV methods, based on multiple criteria (Alkaradaghi et al., 2020). In 2019, Yap et al. provided a systematic overview of the application of decision-making methods based on multiple criteria for location selection (Yap et al., 2019). In 2018, Syam et al applied multi-criteria decision-making methods to select the optimal location of a central spare parts warehouse for a certain taxi company in Indonesia (Syam et al., 2018). In 2018, Mulia explored a company's choice of location in the digital age and whether it still matters (Mulia, 2018). In 2013, Chakraborty et al. applied multi-criteria decision-making methods for choosing the location of the distribution center (Chakraborty et al., 2013). In 2004, Cheng and Li conducted a survey of quantitative methods for project site selection (Cheng and Li, 2004). In 1997, Yang and Lee applied the AHP decision model to facility location selection (Yang and Lee, 1997). In 2024, Stefanov applied multi-criteria decision-making methods for choosing the location of the main warehouse in a company with dispersed centers (Stefanov, 2024). In 2016, during the preparation of his doctoral thesis, Rangelović defined optimization models for choosing the location of production facilities in the function of local economic development (Rangelovic, 2016). In 2014, Marković applied multi-criteria decision-making methods to define regional logistics models for transport systems during the preparation of his doctoral dissertation (Markovic, 2014). There are many other studies related to this question.

According to the above, we can note that there are a number of authors who have been engaged in research related to the application of MCDM to solve the problem of choosing the location of capital facilities. The VIKOR method has so far been very little used for solving problems in logistics, although it is one of the most frequently applied methods from the group of methods for MCDM. In this paper, the VIKOR method will be applied in order to show that this method can be very successfully applied to the selection of the warehouse location, and therefore to solving various problems in logistics. In this paper, the VIKOR method will be applied to solve the logistical problem related to the choice of the location of the main warehouse in a company with several subsidiaries (Mijalkovski et al., 2021b). This method will be applied, in order to show that it can be very successfully applied to the selection of the location of the warehouse, and therefore to solving various problems in logistics.

II. METHODS FOR MULTI-CRITERIA DECISION MAKING

A large number of MCDM methods have been developed that can be applied to solve various problems in logistics. The most commonly used MCDM methods are: ELECTRE method (ÉLimination Et Choix Traduisant la REalité), PROMETHEE method (Preference Ranking Organization METHod for Enrichment of Evaluations), AHP method (Analytic Hierarchy Process), ANP method (Analytic Network Process), NNP method (Neural Network Process), VIKOR method (VIseKriterijumska Optimizacija I Kompromisno Resenje), TOPSIS method (Technique for Order of Preference by Similarity to Ideal Solution), EDAS method (Evaluation Based on Distance from Average Solution), WLC method (Weighted Linear Combination), AHP - PROMETHEE integrated method etc. (Mijalkovski et al., 2023).

Common to all MCDM methods is to choose between several available alternatives, based on several influential criteria. In order to be able to apply decision-making, it is necessary that at least two alternatives are available, and the maximum number of alternatives is not limited. When making decisions, alternatives are compared with each other according to a larger number of influential criteria that have different weights, that is, the impact of the alternatives. The weight of the criteria can be decided in consultation with a larger group of experts from the relevant field, in order to minimize subjectivity in the optimization. The weights are defined in such a way that each expert gives his opinion on the weights of the criteria, and then the mean value is calculated and used in further calculations. The sum of weights for all criteria must be equal to one. Criteria have their purpose, that is, they can aim for a maximum (max) or a minimum (min). Some criteria are classified as quantitative (can be calculated or measured), and some criteria are

doi: 10.2478/jlst-2024-0003

classified as qualitative (cannot be calculated or measured). Qualitative criteria are defined descriptively, so they can be used in further calculations, they need to be transformed into numerical values. This transformation can be done using an interval scale, a bipolar scale, a qualitative scale, a linear transformation scale, a ratio scale, an ordinal scale, etc. In this paper, an interval scale will be used, with the help of which qualitative values will be transformed into quantitative ones (Mijalkovski et al., 2021a).

The VIKOR method was proposed by Oprichović in 1998, where an alternative is chosen from a group of alternatives as a compromise solution and thus the final decision is made. This method got its name from the Serbian name "VIsekriterijumskog KOmpromisnog Rangiranja ", which in translation means "Multi-criteria optimization and compromise solution". According to this method, the closest valid solution to the ideal solution is a compromise solution (Baloyi and Meyer, 2020; Sitorus et al., 2019). Ranking and selection according to this method is done from a set of alternatives with the presence of several criteria. A multi-criteria ranking index was introduced based on a certain measure of closeness to the ideal solution, i.e. distance from the goal (Gao et al., 2019). According to this method, the ranking of alternatives is done according to three scalar values, which are independently evaluated according to the criteria. The ranking of alternatives according to the VIKOR method takes place in several steps (Opricović and Tzeng, 2004), namely:

- Step 1: Determination of the best and worst values of all criteria. If the criterion represents a benefit, then it is better to be as high as possible. If the criterion represents a cost, then it is better to be as low as possible;
- Step 2: Calculation of the measure of utility and measure of regret, the weight of the criteria and the expression of their relative importance;
- Step 3: Calculating the weight of the strategy for the criteria or the maximum benefit of the group;
- Step 4: Ranking the alternatives according to the previously calculated values, arranging them in descending order. The results represent three rankings;
- Step 5: A compromise solution is proposed for the best-ranked alternative, if both conditions are met:
  - Condition 1: An acceptable advantage;
  - Condition 2: Acceptable stability in decision-making.

If one of the conditions is not met, then a set of compromise solutions is proposed, consisting of:

- Alternatives A' and A", if only the second condition is not satisfied;
- Alternatives A', A",..., Am, if the first condition is not satisfied.

The alternative with the lowest value is adopted as the best alternative. The result of the ranking of alternatives is a compromise list of alternatives and a compromise solution with a certain rate of preference.

III. CASE STUDY

In this paper, a company that deals with the use, maintenance and management of irrigation and drainage systems at the level of the whole country will be considered. The purpose of the existence of this company is: providing services to irrigation users, supplying raw water utility companies that produce drinking water, water for the economic needs (this includes electricity production), arranging riverbeds and dewatering of water discharged from production plants.

The composition of this company includes 14 branches in different cities across the country, that is, it has 14 dispersed centers. Based on several parameters, 4 subsidiaries can be singled out, which represent the most significant and influential subsidiaries compared to the others. The parameters by which the most significant subsidiaries are distinguished are: annual revenues, number of warehouses they have, number of employees, location, municipalities they cover and significance at the state level.

The subsidiaries of the company that have been singled out as the most significant represent alternatives and will be used to select the optimal location for setting up the main warehouse of spare parts and consumables throughout the company. Alternatives for the given example would be:

- A_1 – Tikves branch;

doi: 10.2478/jlst-2024-0003

- A_2 – Bregalnica branch;
- A_3 – Sveti Nikole branch;
- A_4 – Skopsko Field branch.

The comparison of alternatives for the optimal selection of the location of the main warehouse will be carried out according to eight influential parameters, which will represent the criteria. The criteria for a specific example will be:

- K_1 – Average size to cover and serve municipalities;
- K_2 – Average annual revenues of the subsidiary company;
- K_3 – Average distance to all branches;
- K_4 – The strategic importance of the subsidiary at the state level;
- K_5 – Average cost of warehouse service;
- K_6 – The need for new employment;
- K_7 – Average delivery of spare parts and consumables;
- K_8 – The need for new facilities.

All criteria have a different impact on alternative solutions. In this research, the weights of the criteria were adopted in consultation with 10 experts in the field of logistics, all with the aim of minimizing subjectivity in the optimization. Each of the experts gave their opinion on the weight of the criteria, and then the mean value was calculated and used for further calculations. Also, the goal the criteria are aimed at is defined: maximum (max) or minimum (min), as well as a category for classifying the criteria, which can be quantitative or qualitative.

All multi-criteria methods use so-called normalized weights, where the sum of all criteria weights should be equal to 1 (one). After normalization by weighting the weights, the normalized criteria are obtained and the nature of the criteria is displayed. Tab. 1 shows the normalized criteria.

Table 1. Normalized criteria and nature of criteria

Criteria	Mark	Normalized weights	Goal	Category
Average size to cover and serve municipalities [number of municipalities]	K_1	0,10	max	Quantitative
Average annual revenues of the subsidiary [million denars]	K_2	0,15	max	Quantitative
Average distance to all branches [kilometers]	K_3	0,14	min	Quantitative
The strategic importance of the subsidiary at the state level	K_4	0,13	max	Qualitative
Average cost of warehouse service	K_5	0,12	min	Qualitative
The need for new employment	K_6	0,09	min	Qualitative
Average delivery of spare parts and consumables	K_7	0,16	max	Qualitative
The need for new facilities	K_8	0,11	min	Qualitative

After the analysis to evaluate the criteria for each alternative, the following multi-criteria model was obtained (Tab. 2).

doi: 10.2478/jlst-2024-0003

Table 2. Multi-criteria model

Alternatives	Criteria							
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8
A_1	5	79	103	Very big	Very small	Very small	Very big	Very small
A_2	5	38	124	Big	Very small	Small	Big	Small
A_3	4	24	101	Very big	Small	Very small	Big	Very small
A_4	8	23	112	Big	Small	Small	Medium	Small
Weights of criteria	0,10	0,15	0,14	0,13	0,12	0,09	0,16	0,11

In order for the qualitative criteria to be used in further calculations, it is necessary to translate them from descriptive numerical values (Tab. 3). For this purpose, we used an interval scale to translate qualitative values into quantitative ones. In further calculations to solve the specific problem, the appropriate equations for the VIKOR method will be used (Mijalkovski et al., 2021b).

Table 3. Input model for the VIKOR method

Alternatives	Criteria							
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8
A_1	5	79	103	9	1	1	9	1
A_2	5	38	124	7	1	3	7	3
A_3	4	24	101	9	3	1	7	1
A_4	8	23	112	7	3	3	5	3
Weights of criteria	0,10	0,15	0,14	0,13	0,12	0,09	0,16	0,11

Table 4. Determination of Best and Worst value

Alternatives	Criteria							
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8
A_1	5,00	79,00	103,00	9,00	1,00	1,00	9,00	1,00
A_2	5,00	38,00	124,00	7,00	1,00	3,00	7,00	3,00
A_3	4,00	24,00	101,00	9,00	3,00	1,00	7,00	1,00
A_4	8,00	23,00	112,00	7,00	3,00	3,00	5,00	3,00
Weights of criteria	0,10	0,15	0,14	0,13	0,12	0,09	0,16	0,11
Best (f_i^+)	8,00	79,00	101,00	9,00	1,00	1,00	9,00	1,00
Worst (f_i^-)	4,00	23,00	124,00	7,00	3,00	3,00	5,00	3,00

Table 5. Computation of S_j, R_j, Q_j

Alternatives	S_j	R_j	Q_j
A_1	0,09	0,08	0,00
A_2	0,73	0,14	0,82
A_3	0,45	0,15	0,67

doi: 10.2478/jlst-2024-0003

A_4	0,83	0,16	1,00
S^+, R^+	0,09	0,08	
S^-, R^-	0,83	0,16	

Table 6. Ranking of alternatives

Alternatives	**S_j**	**R_j**	**Q_j**	**Rank**
A_1	0,09	0,08	0,00	1
A_2	0,73	0,14	0,82	3
A_3	0,45	0,15	0,67	2
A_4	0,83	0,16	1,00	4

According to the ranking of the minimum values for "Q", a proposed compromise solution is obtained, which in this case does not meet the first condition, so the next alternative that meets the condition is taken. The second condition is met.

Condition 1: Acceptable advantage:

$$Q(A") - Q(A') \geq DQ$$
$$0{,}67 - 0{,}00 = 0{,}67 < 0.33$$
$$DQ = \frac{1}{4-1} = \frac{1}{3} = 0.33$$
$$Q(A''') - Q(A') \geq DQ$$
$$0{,}82 - 0{,}00 = 0{,}82 > 0.33$$

Condition 2: Acceptable stability in decision making:

Alternative A' (A_1) is the best ranked by R_j.

This compromise solution is stable within a decision-making process and that concludes the decision-making process.

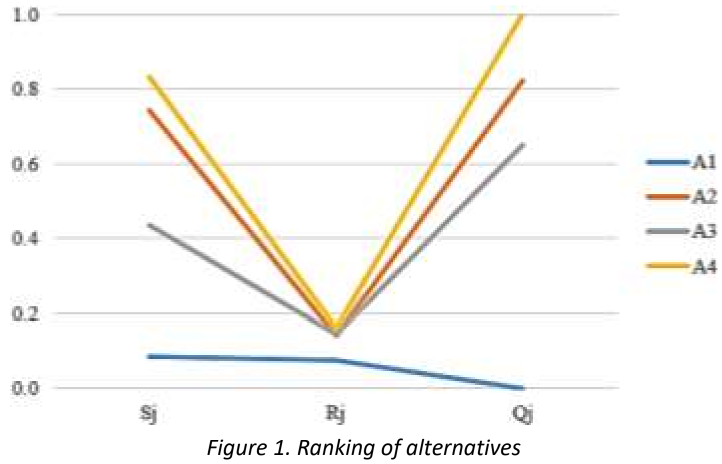

Figure 1. Ranking of alternatives

Tab. 6 and Fig. 1 show that alternative A_1 (Tikves branch) has the lowest value and was chosen as the most acceptable location for the construction of the main warehouse of spare parts and consumables for the needs of companies from dispersed centers. Alternative A_4 (Skopsko Field branch) has the highest value and represents the worst ranked alternative, i.e. the most unacceptable location for the construction of the main warehouse. Alternative A_3 (Sveti Nikole branch) is the second-ranked location, and alternative A_2 (Bregalnica branch) is the third-ranked location.

doi: 10.2478/jlst-2024-0003

Based on everything that has been said so far, we can conclude that the VIKOR method can be successfully used to solve the problem of choosing the location of the main warehouse, as well as many other different problems in logistics. The advantage of this method, as well as other methods for MCDM, compared to classic methodologies for location selection, is that they take into account a large number of influential parameters.

In classical site selection methodologies, only two parameters, quantities and distances, are usually considered. The quantities represent all the quantities of materials that need to be stored. Distances represent the distance needed to transport materials from the supplier (producer) to the warehouse, as well as the distance needed to transport materials from the warehouse to the consumer.

MCDM methods take into account a large number of influential parameters and thus the most optimal choice of location is obtained. In the concrete example, eight influential parameters of different weights, representing criteria, were considered, and based on them, the optimal choice of the location of the main warehouse was achieved. It actually represents the main advantage and the need for the application of MCDM, to solve various problems in logistics.

IV. CONCLUSION

Engineers in charge of making strategic decisions have a very big responsibility, because the decisions they make directly affect the successful functioning of the company itself. Due to the great responsibility and complexity of the problem, it is necessary to take into account as many influential parameters as possible, all in order to choose the most appropriate and optimal decision. When decisions are made about some strategic problems, such as the choice of location for the main warehouse, representatives of several departments are involved, namely: planning, production, logistics and financing.

MCDM methods can be very successfully applied in strategic decision-making processes in companies, where a large number of influential parameters can be taken into account with their help. There are several methods of the group of methods for MCDM, such as: EDAS, VIKOR, TOPSIS, PROMETHEE, ELECTRE, AHP, ANP and others. In this paper, the VIKOR method was used and with its help the location of the main warehouse was chosen, in order to show that this method can be used very successfully to solve complex problems in logistics. When solving the problem of choosing the location of the main warehouse, four alternatives were considered and compared based on eight criteria. At the end of solving the problem, we came to the conclusion that the most acceptable location is the Tikves Branch.

The right choice for the optimal location of the main warehouse will bring more benefits, such as: minimizing the costs of new employment and construction of new facilities, serving the warehouse and all branches, as well as taking advantage of the maximum strategic, geographical, practical and economic importance of branches.

The disadvantage of the VIKOR method, as well as other methods for MCDM, is the possibility of subjectivity in solving problems. In order to reduce the subjectivity of this method, when solving a specific problem, 10 experts were hired to define the weights of the criteria, and then the average values for the weights were calculated and used during the calculations.

The direction of further research on this issue is the possibility of applying multiple methods for MCDM, that is, solving a specific problem with the help of multiple methods for MCDM. After obtaining the final solutions and ranking the alternatives, according to different methods for MCDM, then the obtained results will be compared and the average ranking of the alternatives will be calculated, which will represent the optimal solution for the given problem. In this way, subjectivity will be completely eliminated and the most optimal solution for a specific problem will be obtained.

Acknowledgment

This paper is based on the research that was carried out during the preparation of the master's thesis on this topic: "Selection of the location of the warehouse of spare parts and consumables for a company with dispersed locations".

doi: 10.2478/jlst-2024-0003

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doi: 10.2478/jlst-2024-0003

Manuscript received by 18 March 2024.

Uporaba metode VIKOR za reševanje problemov v logistiki

Povzetek – Ko podjetja sprejemajo strateške odločitve, morajo odgovorne osebe upoštevati čim več vplivnih parametrov, da bi bila rešitev danega problema optimalna. To pomeni, da sprejmejo najustreznejšo odločitev. Večkriterijsko odločanje (VKO) ima zelo široko uporabo pri reševanju zapletenih in pomembnih vprašanj, pri katerih je še posebej pomembno, da podjetje sprejme najustreznejšo odločitev. Sprejetje optimalne odločitve za določen problem neposredno vpliva na finančno uspešnost določenega podjetja.

V tem prispevku bomo uporabili metoda VIKOR, ki do zdaj ni bila uporabljena za reševanje problemov, povezanih z izbiro lokacije skladišča, se pa pogosto in uspešno uporablja za reševanje različnih kompleksnih problemov pri uporabi večkriterijskega odločanja. Namen tega prispevka je pokazati, da je mogoče metodo VIKOR uspešno uporabiti za izbiro optimalne lokacije skladišča za podjetje, ki ima podružnice na več lokacijah.

Ključne besede - izbira, lokacija, skladišče, večkriterijsko odločanje, metoda VIKOR