TRANSPORT & *LOGISTICS:*
the International Journal
ISSN 2406-1069

Article history:
Received 10th February 2024
Accepted 13th May 2024
Available online 18th May 2024
https://doi.org/10.46544/TNL.v24n56.05

Article citation info: Mijalkovski, S., Stefanov, V., Mirakovski, D., Application of the TOPSIS method for selecting the location of the main warehouse. Transport & Logistics: the International Journal, 2024; Vol. 24, No. 56, https://doi.org/10.46544/TNL.v24n56.05

Application of the TOPSIS method for selecting the location of the main warehouse

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Abstract:
When making strategic decisions in the company, it is necessary to analyze the problem in detail and take into account as many influential parameters as possible in order to make the optimal decision. Successful management of any company is based on making the right decisions at the right time. One of the most important decisions in industrial logistics is choosing the location of the main warehouse for the needs of a given company, which has several dispersed centers. The application of multi-criteria decision-making methods can be applied to solve various problems in industry and everyday life.
In this paper, the TOPSIS method will be applied to select the most optimal location of the main warehouse for the storage of spare parts and consumables, for the needs of a given company with dispersed centers.

Key words:
location selection, warehouse, multi-criteria decision-making methods, TOPSIS method

Introduction

The decision a company makes selecting a factory or warehouse location has a very large impact on its own business in the future. This means that the factory or warehouse is well located in the current economic and technological conditions, but in the near future it may not be optimally located. Current decisions on choosing a factory or warehouse location directly affect: logistics costs, marketing, production and finance.

Companies use quantitative and qualitative criteria when deciding on a factory or warehouse location. Making a decision is the process of choosing one alternative from several possible alternatives for a specific problem. To be able to apply decision making, we need to have at least two proposed alternatives, and the maximum number of alternatives is not limited. Optimization for solving a given problem can be single-criteria and multi-criteria. Single-criterion optimization uses only one criterion during optimization, thereby reducing the actual solution to a given problem. Multi-criteria optimization uses several criteria, so that the obtained solution is the most optimal for the given problem. There are a number of methods for multi-criteria decision-making, which can be applied when making a strategic decision (Tzeng and Huang, 2011). The most commonly used methods for multi-criteria decision-making are: AHP, ANP, ELECTRE, PROMETHEE, TOPSIS, VIKOR, EDAS, TODIM and others. The advantage of multi-criteria decision-making methods compared to single-criteria methods is that a larger number of influential parameters are taken into account, which represent criteria and against which the proposed alternatives are compared. The criteria have a different impact on each alternative, which is why each criterion is assigned different weights. The greater the number of criteria, the more optimal the resulting solution will be. One of the most commonly used methods for multi-criteria decision-making and which, in the author's opinion, gives very solid results in terms of optimization is the TOPSIS method, which will be applied in this paper for the optimal selection of main warehouse locations.

1 Methods and methodology

1.1 Selection of warehouse location

Making a decision on the choice of location usually requires significant financial investments, whether it is the construction of a new facility or the relocation of an existing facility. Significant funding is required, as new factories or warehouses can use the latest technologies to save on some further running costs and improve services. Moving a factory or warehouse from one location to another provides a higher level of service, and the end result is a competitive advantage in the market. The need to modernize a factory or warehouse usually requires a change in its location (Stefanov et al., 2023).

When a company makes a decision to invest in an existing factory or warehouse, it is necessary to perform a detailed analysis of whether the current location is suitable for the factory or warehouse, in relation to the location for current and future consumers and producers.

The changing market forces companies to analyze warehouse locations in detail. Competitive pressure is forcing the company to review the level of logistics services and costs generated by its warehouse network. To maintain and improve their competitive edge in the market, companies often examine their own existing warehouse locations to improve services and reduce costs. When making the final decision about the warehouse network within the company, new modes and technologies of transportation must be taken into account.

There are a large number of influential parameters, which have a very large influence when choosing a location, that is, it is necessary to optimize several requirements between investors, employees and consumers. The most important requirements are as follows: the investor is looking for the development of the company and an increase in profits, the employee is looking for relaxation at work and a solid income, and the consumer is looking for good service and a low price.

Multi-criteria decision-making methods enable the optimal choice of factory or warehouse location, as a large number of influential parameters can be taken into account (Mijalkovski et al., 2023). In this paper, the TOPSIS method will be applied (Mijalkovski et al., 2022).

There are a large number of authors who have researched in the direction of location selection using multi-criteria decision-making methods, such as: In 2016, Rangelović researched models for optimization in the selection of the location of production facilities in the function of local economic development, during the preparation of his doctoral dissertation. In 2014, during the preparation of his doctoral dissertation, Marković researched the regional logistics model of transport systems using multi-criteria decision-making methods. In 2018, Syam et al., used Determining the optimal location of central spare part warehouse for the leading taxi company in Indonesia. In 2021, Margana et al., used Determination of distribution center location in the Xyz small and medium enterprise (Sme) using center of gravity method and many other researchers.

1.2 TOPSIS method

The TOPSIS method was first proposed and developed by Hwang and Yoon (1981), while it was later extended and improved by Chen (2000). According to the TOPSIS method, the best-ranked alternative is the one that is closest to the positive ideal solution (PIS) and is also the furthest from the negative ideal solution (NIS). The positive ideal solution (PIS) represents a hypothetical alternative that maximizes the benefit criterion (BC) while at the same time minimizing the cost criterion (CC). The negative ideal solution (NIS) is the opposite of the positive ideal solution (PIS), that is, it maximizes the cost criterion (CC) and minimizes the benefit criterion (BC). According to this method, the best alternative is the one that has the smallest Euclidean distance from the PIS and the largest distance from the NIS (Parida, 2019; Kun et al., 2013), that is, the TOPSIS method simultaneously takes into account the distance to the PIS and to the NIS. The ideal or optimal solution is the solution that is closest to the PIS and the furthest from the NIS. When using the TOPSIS method, the calculations take place according to the following steps (Asr et al., 2015):
Step 1. After the decision matrix is compiled, a normalized decision matrix is formed;
Step 2. The weighted, normalized decision matrix is obtained by multiplying the normalized decision matrix and the weight of the criteria;
Step 3. In this step, the negative and positive ideal solutions are determined. The ideal positive solution, is made of all the best performance scores and the negative ideal solution, is made of all the worst performance scores for the criteria in the weighted, normalized decision matrix;
Step 4. The distance of each alternative from PIS and NIS is calculated using the *n*-dimensional Euclidean distance;
Step 5. In this step, the relative closeness to the ideal solution is calculated;
Step 6. Preference ranking in descending order of value.

2 Results

In order to ensure the timely, efficient and coordinated performance of water management activities throughout the country, a special company was established. This company has 14 branches in several cities across the country, of which 4 branches can be singled out as the most significant. The company uses, maintains and manages irrigation and drainage systems as a whole, in order to provide services to irrigation users, supply raw water utility companies that produce drinking water, water for business needs (this includes electricity generation), river bed development, drainage and disposal of discharged water (Stefanov, 2024).

Alternatives for choosing a location for placing the main warehouse of spare parts and consumables at the level of the entire company will be represented by the four most important branches of the company. Alternatives for a concrete example will be:

A_1 – Branch in Kavadarci;
A_2 – Branch in Kocani;
A_3 – Branch in Sveti Nikole;
A_4 – Branch in Skopje.

The comparison of alternatives, ie locations, will be done according to several influential parameters, which will represent the criteria. The criteria for a specific example will be:

C_1 – The strategic importance of the location (branch) at the state level;
C_2 – Average annual revenue of the location (branch);
C_3 - Average distance to all branches;
C_4 - Average size to cover and serve municipalities;
C_5 - Average cost of warehouse service;
C_6 – The need for new facilities;
C_7 – Average delivery of spare parts and consumables;
C_8 – The need for new employment.

Each of the criteria has its own influence (weight) on alternative solutions. In order to perform the definition of the weights of the criterion functions on the alternative solutions were made:

- Analyzes of techno-economic analyzes and other professional information;
- Consultations and surveys of logistics experts;
- Calculation of the mean (average) values of weights obtained from the above procedures.

All multi-criteria methods use so-called normalized weights, that is, the sum of all criteria weights should be equal to 1 (one). After performing the normalization by weighting the weights, the normalized criteria are obtained and the nature of the criteria is displayed. All criteria have their own goal, that is, they aim for a maximum or a minimum. In this particular case, criteria C_1, C_2, C_4 and C_7 tend to the maximum (max), while criteria C_3, C_5, C_6 and C_8 tend to the minimum (min). Criteria can be qualitative or quantitative. Table 1 shows the normalized criteria.

***Tab. 1** Normalized criteria and nature of criteria*

Criteria	Mark	Normalized weights	Goal	Category
The strategic importance of the location (branch) at the state level	C_1	0,14	max	Qualitative
Average annual revenue of the location (branch) [millions of dollars]	C_2	0,16	max	Quantitative
Average distance to all branches [kilometers]	C_3	0,13	min	Quantitative
Average size to cover and serve municipalities [number of municipalities]	C_4	0,09	max	Quantitative
Average cost of warehouse service	C_5	0,11	min	Qualitative
The need for new facilities	C_6	0,12	min	Qualitative

Tab. 1 *Normalized criteria and nature of criteria-continued*

Criteria	Mark	Normalized weights	Goal	Category
Average delivery of spare parts and consumables	C_7	0,17	max	Qualitative
The need for new employment	C_8	0,08	min	Qualitative

After the analysis for the assessment of individual criteria for each alternative solution, the following multi-criteria model was obtained (table 2).

Tab. 2 *Multi-criteria model*

Alternatives	**Criteria**							
	C₁	**C₂**	**C₃**	**C₄**	**C₅**	**C₆**	**C₇**	**C₈**
Goal	**max**	**max**	**min**	**max**	**min**	**min**	**max**	**min**
A₁	Very big	78,5	102	5	Very small	Very small	Very big	Very small
A₂	Very big	37,5	123	5	Very small	Very small	Big	Very small
A₃	Very big	24	100	4	Small	Very small	Big	Very small
A₄	Big	22,5	111	8	Small	Small	Medium	Small
Weights	0,14	0,16	0,13	0,09	0,11	0,12	0,17	0,08

After the transformation of the attribute quality, the input multi-criteria model is obtained (table 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 TOPSIS method will be used.

Tab. 3 *Input model for the TOPSIS method*

Alternatives	**Criteria**							
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**
Goal	**max**	**max**	**min**	**max**	**min**	**min**	**max**	**min**
A_1	9	78,5	102	5	1	1	9	1
A_2	9	37,5	123	5	1	1	7	1
A_3	9	24	100	4	3	1	7	1
A_4	7	22,5	111	8	3	3	5	3
Weights	0,14	0,16	0,13	0,09	0,11	0,12	0,17	0,08

Tab 4. *Normalized decision matrix*

Alternatives	**Criteria**							
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**
Goal	**max**	**max**	**min**	**max**	**min**	**min**	**max**	**min**
A_1	0,5267	0,8440	0,4663	0,4385	0,2236	0,2887	0,6301	0,2887
A_2	0,5267	0,4032	0,5623	0,4385	0,2236	0,2887	0,4901	0,2887
A_3	0,5267	0,2580	0,4571	0,3508	0,6708	0,2887	0,4901	0,2887
A_4	0,4096	0,2419	0,5074	0,7016	0,6708	0,8660	0,3501	0,8660

***Tab. 5** Final weighted, normalized matrix*

Alternatives	Criteria							
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Goal	**max**	**max**	**min**	**max**	**min**	**min**	**max**	**min**
A_1	0,0737	0,1350	0,0606	0,0395	0,0246	0,0346	0,1071	0,0231
A_2	0,0737	0,0645	0,0731	0,0395	0,0246	0,0346	0,0833	0,0231
A_3	0,0737	0,0413	0,0594	0,0316	0,0738	0,0346	0,0833	0,0231
A_4	0,0574	0,0387	0,0660	0,0631	0,0738	0,1039	0,0595	0,0693

***Tab. 6** Ideal positive and negative solutions for each criterion*

Ideal solutions	Criteria							
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Ideal positive solutions (A^+)	0,0737	0,1350	0,0594	0,0631	0,0246	0,0346	0,1071	0,0231
Ideal negative solutions (A^-)	0,0574	0,0387	0,0731	0,0316	0,0738	0,1039	0,0595	0,0693

***Tab. 7** Alternative distances and their relative closeness criteria*

Alternatives	D_j^+	D_j^-	C_j^+
A_1	0,0237	0,1462	0,8605
A_2	0,0793	0,1045	0,5685
A_3	0,1130	0,0892	0,4412
A_4	0,1456	0,0324	0,1818

***Tab. 8** Ranking of alternatives*

Alternatives	C_j^+	Rank
A_1	0,8605	1
A_2	0,5685	2
A_3	0,4412	3
A_4	0,1818	4

Table 8 shows that alternative "A_1", i.e. Branch in Kavadarci (figure 1) has the highest value and was chosen as the most acceptable location for the construction of the main warehouse of spare parts and consumables for the company's needs. Alternative "A_2" is in the second rank, then alternative "A_3" and the last ranked alternative is "A_4" ($A_1 \rightarrow A_2 \rightarrow A_3 \rightarrow A_4$).

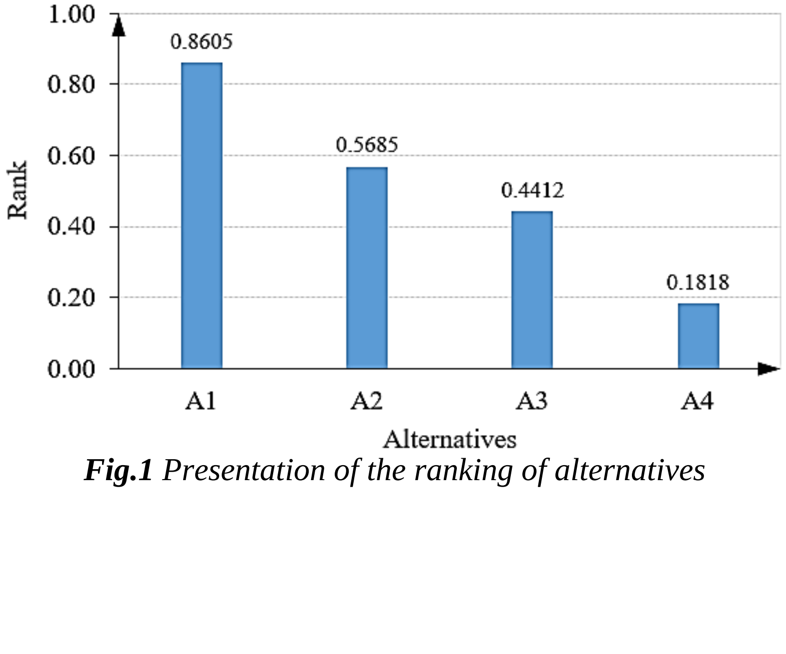

***Fig.1** Presentation of the ranking of alternatives*

3 Conclusions

Every company, when choosing a location for a factory or warehouse, must take into account many influencing factors. The decision to choose a location for a warehouse is a very complex process, influenced by many factors. The importance of factors varies from industry to industry. Many factors that influence the choice of location are qualitative and very difficult to measure, they represent management's impressions of the views of workers, citizens and public services on a potential location.

The management team has the greatest influence on the choice of factory or warehouse location. When making the final decision, representatives of production, engineering, logistics, finance and planning (if such a department exists in the company) are usually involved.

Multi-criteria decision-making methods enable the selection of the most suitable location, considering a large number of influential parameters. The selection of a location for a factory or a warehouse can be made using several methods for multi-criteria decision-making, such as: AHP, ELECTRE, PROMETHEE, TOPSIS, VIKOR, EDAS and others. In this paper, the TOPSIS method was used to select the location of the warehouse, where several alternatives (locations) were considered, which were compared with each other based on several influential factors, and the conclusion was reached that the most acceptable location is the branch in Kavadarci.

If several methods of multi-criteria optimization are used, the obtained results will be compared and in this way the most suitable location for the construction of the warehouse will be obtained, which is of great importance for solving this very complex issue.

The next step in the research of this problem is the application of FUZZY methods for multi-criteria decision-making, as well as their mutual comparison of the obtained results.

Acknowledgement

This paper is based on the research conducted during the preparation of the master's thesis entitled: "Selection of the location of the warehouse of spare parts and consumables for a company with dispersed locations".

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