Journal of Intelligent Management Decision
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A Multi-Criteria Decision Framework for Parcel Locker Location Selection in the Area of the Visoko Distribution Center

Danira Durmić[1], Željko Stević[1,2*]

[1] Faculty of Transport and Traffic Engineering, University of East Sarajevo, 74000 Doboj, Bosnia and Herzegovina
[2] Department of Industrial Management Engineering, Korea University, 02841 Seoul, South Korea

* Correspondence: Željko Stević (zeljko.stevic@sf.ues.rs.ba)

Received: 01-18-2026 **Revised:** 03-28-2026 **Accepted:** 04-07-2026

Citation: D. Durmić and Ž. Stević, "A multi-criteria decision framework for parcel locker location selection in the area of the Visoko distribution center," *J. Intell Manag. Decis.*, vol. 5, no. 2, pp. 129–138, 2026. https://doi.org/10.56578/jimd050203.

Abstract: The rapid expansion of e-commerce has intensified the complexity of last-mile delivery, where increasing parcel volumes and urban constraints continue to challenge traditional distribution models. Among emerging solutions, parcel lockers have gained attention for their potential to improve delivery efficiency while reducing operational and environmental pressures. However, their effectiveness largely depends on appropriate location planning, which requires the simultaneous consideration of multiple and often conflicting criteria. This study develops a multi-criteria decision framework for parcel locker location selection by integrating the Opinion Weight Criteria Method (OWCM) and the Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS) method. The proposed framework enables the systematic evaluation of alternative locations by combining structured expert judgment with compromise-based ranking. Criteria weights are derived through OWCM to ensure consistency in preference representation, while MARCOS is employed to assess alternatives based on their relative distance from ideal and anti-ideal solutions. The model is applied within a last-mile delivery context to examine its practical applicability. The results identify the most suitable location among a set of feasible alternatives and demonstrate stable performance under varying weighting scenarios. Sensitivity and comparative analyses confirm that the ranking outcomes remain consistent across different conditions and methodological configurations. The findings provide a structured approach to location planning in urban logistics and offer practical support for decision-makers seeking to deploy parcel locker systems under complex operational environments. The proposed framework can be extended to similar decision problems involving infrastructure placement and multi-criteria evaluation.

Keywords: Parcel lockers; Last-mile delivery; Urban logistics; Multi-criteria decision-making; Opinion Weight Criteria Method; Measurement of Alternatives and Ranking according to Compromise Solution

1 Introduction

Over the past decade, the e-commerce market for all products ranging from high-value durables to low-value consumer goods has experienced tremendous growth, but also major changes. The expansion of this market has coincided with the rise of direct deliveries to end users. In parallel, this development has highlighted problems in the final part of the supply chain [1]. Urban areas are particularly affected by last-mile delivery challenges due to high population density and high-volume traffic flows. Studies have shown that last-mile deliveries can account for up to half of total logistics costs, even though they represent only a small portion of the total transport distance. Improving the efficiency of last-mile deliveries has become a key objective for logistics companies. Although the physical distance is relatively short, this stage brings the highest logistical costs, delays and environmental challenges. Problems associated with this stage include the lack of parking spaces, limited access to central city areas, traffic congestion and delivery times [2]. Solutions that combine technologies, concepts and initiatives of urban logistics can be defined for the implementation of the last-mile delivery. The successful implementation of these solutions depends on the characteristics of the city, the goals of the participants and the possibilities of achieving economic, environmental, and social sustainability [3]. One of the most modern solutions to these challenges is the application of parcel lockers—automated systems for collecting and sending shipments, which allow users greater flexibility in collecting, while at the same time reducing the burden on traditional delivery routes. The fast pace of life and traffic congestion make parcel delivery more difficult and expensive, while parcel lockers offer a more efficient way of receiving and sending shipments 24 hours a day, seven days a week [4].

In order to determine the optimal locations for the installation of parcel lockers, it is necessary to apply scientifically grounded decision-making methods that include a large number of criteria. In this sense, multi-criteria decision-making (MCDM) represents a very useful tool for everyday decision-making in various areas [5]. By combining different MCDM methods, it is possible to reach reliable and objective decisions in areas such as urban logistics and distribution. The objective of this research is to apply a model for selecting optimal locations for parcel lockers in urban areas, with a particular focus on the area served by the Visoko distribution center. The research seeks to identify locations that will be accessible to users, have efficient operational implementation and use logistical resources rationally.

The main scientific contribution of the paper lies in the application of the integrated Opinion Weight Criteria Method-Measurement of Alternatives and Ranking according to Compromise Solution (OWCM-MARCOS) model for selecting locations for the installation of parcel lockers. The OWCM method is used to objectively determine the weights of the criteria, which will reduce subjectivity in the evaluation process, while the MARCOS method allows for the ranking of locations based on their distance from the ideal and anti-ideal solutions.

2 Background

The development of information technologies and the growth of e-commerce in the last decade have significantly changed the demands on logistics systems, particularly in urban areas. Traditional delivery models are increasingly struggling to meet modern challenges manifested through increased shipment volumes, traffic congestion, environmental constraints, and high user expectations. These challenges are particularly pronounced in the delivery segment called last-mile delivery, i.e., the final stage of delivery that includes the route from the distribution center to the end user [6]. The goal of urban logistics management is to reduce the negative consequences of transport, such as congestion, emissions of harmful gases and noise, while ensuring timely and accurate delivery to users [7]. To achieve these goals, cooperation among local authorities, logistics operators and the private sector is necessary, which implies the alignment of regulatory policies, business models and innovative technological solutions [8]. In essence, the concept of urban logistics management is not limited to transport companies, but includes a whole range of participants, from local governments to end users. Its development is aimed at creating sustainable cities that balance economic needs, technological innovation and environmental protection.

Parcel lockers increasingly emerge as one of key solutions for optimizing last-mile delivery, particularly in transition countries. The development of e-commerce and changes in consumer habits have resulted in an increased demand for flexible and reliable delivery methods, which has led to a need for innovative logistics approaches [9]. Parcel lockers are automated stations for storing and collecting parcels, which allow users to choose their own pickup time, significantly reducing the problem of failed deliveries and multiple delivery attempts [10]. The advantages of introducing parcel lockers are reflected in several segments. First, they enable the consolidation of deliveries in one place, which reduces the number of required trips and optimizes vehicle utilization. Second, their application reduces CO_2 emissions and noise in urban areas, which contributes to the sustainable development of urban transport. Third, parcel lockers provide users with greater security and flexibility, as they allow the pickup of parcels at any time of the day, regardless of the working hours of courier services [11]. However, the implementation of parcel lockers also faces certain challenges. The most common obstacles include high initial setup costs, the need to secure attractive locations, and compliance with regulatory frameworks and safety standards. Despite these difficulties, a growing number of cities recognize parcel lockers as an integral part of smart and sustainable logistics, as they enable a balance between consumer demands, operator costs, and environmental protection [12].

The problem of selecting locations is a task that requires the simultaneous consideration of multiple criteria. Therefore, multi-criteria decision-making methods are increasingly used. Determining the weighting of multiple criteria is a key step in multi-criteria decision-making, as it directly affects the final ranking of alternatives. Real-world problems usually do not have criteria of equal significance, and it is necessary to define the significance factors of individual criteria by using appropriate weighting coefficients for the criteria [13]. The OWCM method was developed to overcome limitations, allowing experts to express their evaluations using linguistic variables. These linguistic assessments are converted into numerical values, ensuring consistency and objectivity in the weighting process [14]. The MARCOS method is a multi-criteria decision-making method that evaluates alternatives based on their distance from the ideal and anti-ideal solutions. By considering both distances simultaneously, this method provides a comprehensive assessment of alternative performance [15]. The method has shown applicability in logistics and transportation research, particularly in location selection and system optimization problems.

3 Research Methodology

The research methodology is designed to provide assessment of potential locations for the installation of parcel lockers in the area of the Visoko distribution center using MCDM methods. It consists of several stages. The initial phase involves the development of a questionnaire with clearly defined criteria and alternatives. The OWCM method was used to calculate the significance of the criteria, while the MARCOS method was used to rank the alternatives. The final phase of the research includes a sensitivity analysis that tested the results of the model, identifying the optimal location. In addition, a comparative analysis was performed using other MCDM methods, such as Additive Ratio Assessment (ARAS), Evaluation Based on Distance from Average Solution (EDAS), and Weighted Aggregated Sum Product Assessment (WASPAS), in order to further confirm the consistency of the obtained results.

3.1 Opinion Weight Criteria Method

The OWCM method has recently been introduced as a technique for determining the weighting coefficients of criteria that combine subjective and objective components, with the aim of eliminating disagreement in assessments. OWCM allows decision-makers to enter their preferences, while ensuring that the final weights are consistent and free of contradictions [16]. Figure 1 shows the steps of the OWCM method.

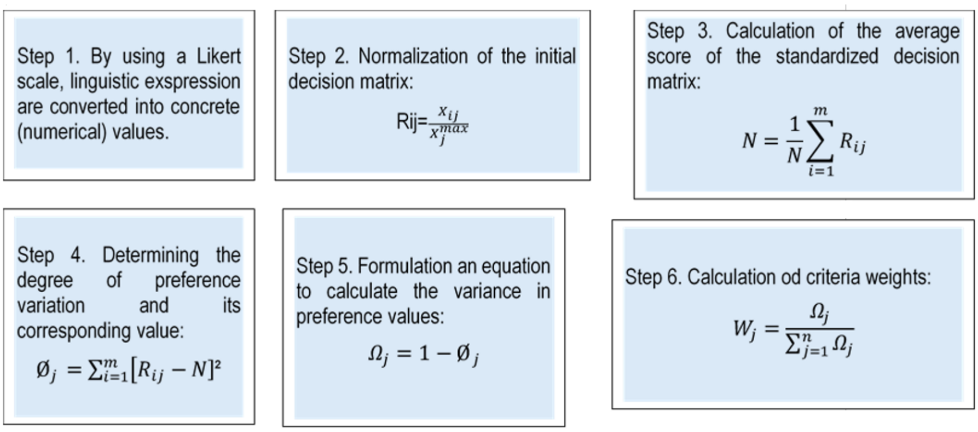


Figure 1. Steps of the Opinion Weight Criteria Method (OWCM)

3.2 Measurement of Alternatives and Ranking According to Compromise Solution Method

After determining the weights of the criteria, the MARCOS method is applied to rank potential parcel locker locations. The MARCOS method ranks alternatives based on their proximity to the ideal and distance from the anti-ideal solution [17]. Figure 2 shows the steps of the MARCOS method.

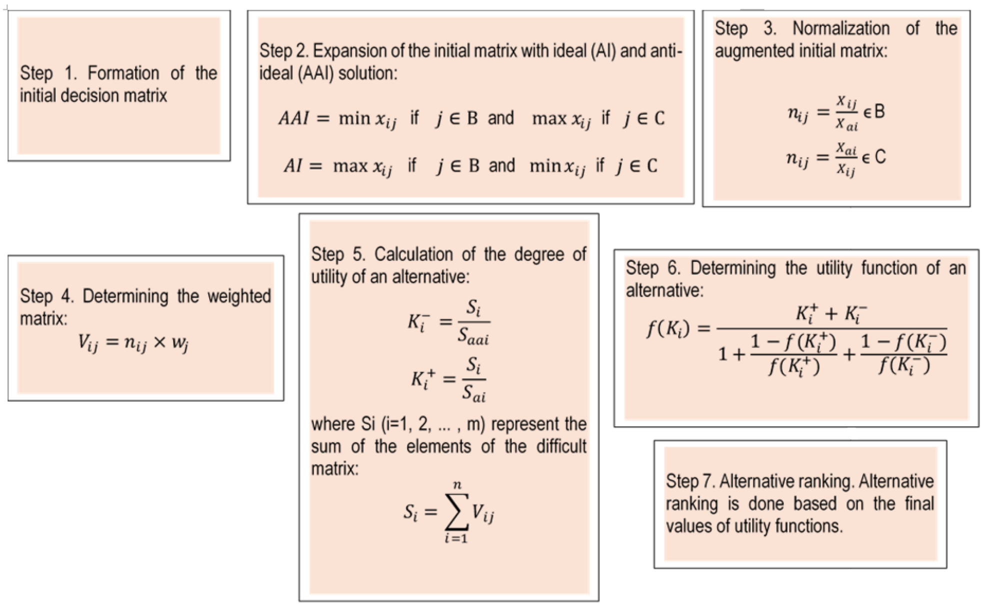


Figure 2. Steps of the Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS) method

4 Case Study: Selection of Locations for Parcel Locker Installation in the Area of the Visoko Distribution Center

The company X-Express provides express delivery services across Bosnia and Herzegovina, with the additional service of sending parcels abroad. With a fleet of over 600 vehicles and 17 distribution centers, the company covers all larger towns, including Visoko, where one of its regional business centers is located. This paper focuses on selecting the most suitable locations for the installation of parcel lockers in the area served by the Visoko distribution center. Figure 3 presents all potential locations, i.e., alternatives for the installation of parcel lockers within the specified geographical area.

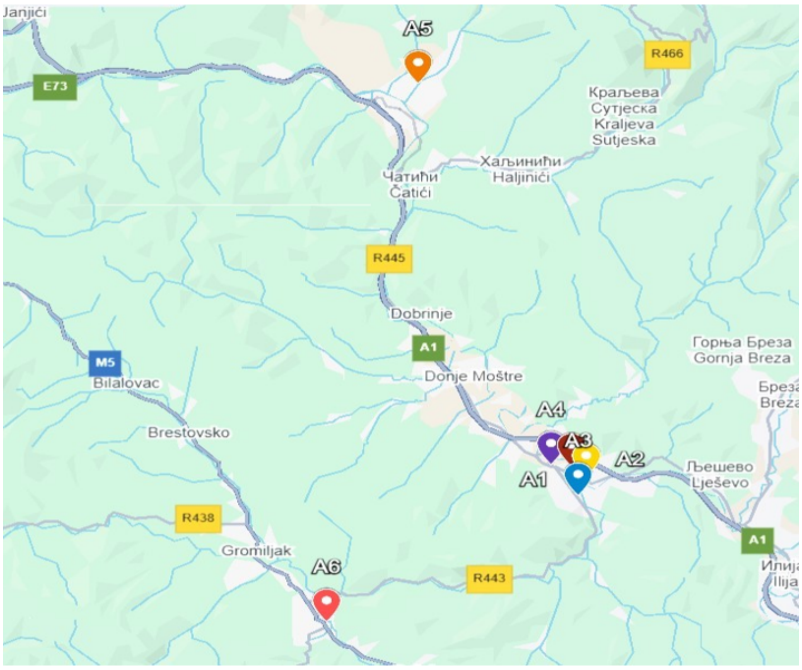


Figure 3. Potential locations of Visoko distribution center

After defining the set of criteria, the following step is the formation of alternatives, i.e., potential locations that are considered for the potential installation of parcel lockers. Data from the considered locations were collected in the period from May 8 to May 16, 2025. The number of shipments within a 5-minute and a 10-minute radius of each potential location for parcel locker installation was considered. The data from the examined period are presented in Table 1.

Table 1. Data from the examined period

Alternative	Town	Street	Location	Number of Shipments (5-min. Walk)	Number of Shipments(10-min. Walk)
A1	Visoko	Patriotske lige	Parking lot at the “Luke” stadium	128	446
A2	Visoko	Bosne srebrne	Bus station	60	305
A3	Visoko	Mule Hodžića	Visoko Market	154	403
A4	Visoko	Arnautovića put	Suša Gas Station	89	398
A5	Kakanj	Ulica branilaca	Trgośped Gas Station	118	262
A6	Kiseljak	Bana Josipa Jelačića	Bingo Shopping Center	271	595

By applying the OWCM method in this paper, the weights of the criteria are calculated. The calculation is made based on 6 alternatives and 7 criteria. The questionnaire created by the managers of the X-Express company will help determine the optimal location for the parcel locker installation, reduce costs and satisfy users. Using linguistic expressions, which represent the first step in the calculation of the OWCM method, the values are converted into numerical values, as shown in Table 2.

Table 2. Data from the examined period

Alternative	C1	C2	C3	C4	C5	C6	C7
A1	2	2	1	3	2	2	2
A2	2	1	1	3	2	4	2
A3	3	4	1	3	2	2	2
A4	1	1	1	1	1	2	1
A5	2	2	3	3	3	3	2
A6	1	2	3	3	1	1	2
MAX	3	4	3	3	3	4	2

This is followed by identifying the maximum value for each criterion. The maximum value for the first criterion is 3, for the second criterion is 4, for the third is 3, for the fourth is 3, for the fifth is 3, for the sixth is 4, and the maximum value for the seventh criterion is 2.

An example of normalization:

$$R_{11} = 2 \div 3 = 0.667$$

The remaining values are shown in Table 3.

Table 3. Normalized values

Alternative	C1	C2	C3	C4	C5	C6	C7
A1	0.667	0.500	0.333	1.000	0.667	0.500	1.000
A2	0.667	0.250	0.333	1.000	0.667	1.000	1.000
A3	1.000	1.000	0.333	1.000	0.667	0.500	1.000
A4	0.333	0.250	0.333	0.333	0.333	0.500	0.500
A5	0.667	0.500	1.000	1.000	1.000	0.750	1.000
A6	0.333	0.500	1.000	1.000	0.333	0.250	1.000
SUM	3.667	3.000	3.333	5.333	3.667	3.500	5.500

After normalization, it is necessary to sum the values for each criterion. The sum of the values for the first criterion is 3.667, for the second is 3.000, for the third is 3.333, for the fourth is 5.333, for the fifth is 3.667, for the sixth is 3.500, and the sum of all values for the seventh criterion is 5.500.

The third step in calculating the weighting coefficients is to calculate the average score of the standardized decision matrix. An example of the calculation is:

$$\text{N} = 1 \div 6 * (3.667) = 0.611$$

The remaining values are shown in Table 4.

Table 4. Average score of the standardized decision matrix

Item	C1	C2	C3	C4	C5	C6	C7
N	0.611	0.500	0.556	0.889	0.611	0.583	0.917

The fourth step is to determine the degree of preference variation and its corresponding values. An example of calculation:

$$\emptyset_j = (0.667 - 0.611)^2 = 0.003$$

The remaining values are shown in Table 5.

The fifth step in calculating the criterion weighting coefficients is to formulate an equation to compute the deviations in preference values. The values are shown in Table 6. An example of calculation:

$$\Omega_j = 1 - 0.315 = 0.685$$

The values need to be summed, and their sum is 4.491.

The sixth step is to calculate the weights of the criteria. These values are shown in Table 7.

Table 5. Degree of preference variation and its corresponding values

Alternative	C1	C2	C3	C4	C5	C6	C7
A1	0.003	0	0.049	0.012	0.003	0.007	0.007
A2	0.003	0.063	0.049	0.012	0.003	0.174	0.007
A3	0.151	0.250	0.049	0.012	0.003	0.007	0.007
A4	0.077	0.063	0.049	0.309	0.077	0.007	0.174
A5	0.003	0	0.198	0.012	0.151	0.028	0.007
A6	0.077	0	0.198	0.012	0.077	0.111	0.007
SUM	0.315	0.375	0.593	0.370	0.315	0.333	0.208

Table 6. Deviation in preference values

Item	C1	C2	C3	C4	C5	C6	C7
Ω_j	0.685	0.625	0.407	0.630	0.685	0.667	0.792

Table 7. Weighting coefficients of criteria

Item	C1	C2	C3	C4	C5	C6	C7
W_j	0.153	0.139	0.091	0.140	0.153	0.148	0.176

An example of calculation:

$$Wj = 0.685 \div 4.491 = 0.153$$

The following section shows the ranking of potential locations using the MARCOS method. The results are presented in Table 8.

Table 8. Ranking of alternatives

Alternative	Si	Ki-	Ki+	fK-	fK+	Ki	Rank
AAI	0.694						
A1	0.850	1.225	0.850	0.410	0.590	0.662	3
A2	0.828	1.192	0.828	0.410	0.590	0.644	4
A3	0.789	1.136	0.789	0.410	0.590	0.614	5
A4	0.979	1.410	0.979	0.410	0.590	0.762	1
A5	0.777	1.119	0.777	0.410	0.590	0.605	6
A6	0.885	1.275	0.885	0.410	0.590	0.689	2
AI	1.000						

In this case, alternative A4 ranks first as the top-ranked, alternative A1 is third as mid-ranked, and alternative A5 is the last.

5 Sensitivity Analysis

Sensitivity analysis is a one of key steps in validating the stability of MCDM models. In practical decision-making environments, expert assessments and criterion weights may vary due to uncertainty, subjective perceptions, or changes in operational priorities. Therefore, it is important to examine how variations in criterion weights affect the final ranking of alternatives. In this study, a sensitivity analysis was conducted by varying the weights of selected criteria while observing changes in the ranking of alternatives. The analysis focused on the most influential criteria identified by the OWCM method, including availability, demand intensity, and operational risk factors.

This section of the paper analyzes changes in weighting coefficients, which vary within the range of 15–90%. The results of changing the weighting coefficients are shown in Figure 4.

The results of the sensitivity analysis indicate that the ranking of alternatives remains stable with moderate changes in the weights of the criteria. The top-ranked alternative maintained the leading position in several scenarios, demonstrating the stability of the proposed OWCM–MARCOS model. Minor variations were noticed in the ranking of lower-ranked alternatives. However, these changes did not affect the overall decision outcome.

The weighting coefficient values range approximately between 0.010 and 0.230, depending on the criteria and the scenarios with changes. After changing the weighting coefficient values of the criteria, a sensitivity analysis was conducted to show how changes in the weighting coefficient values affect the final ranking, across the 42 scenarios shown in Figure 5.

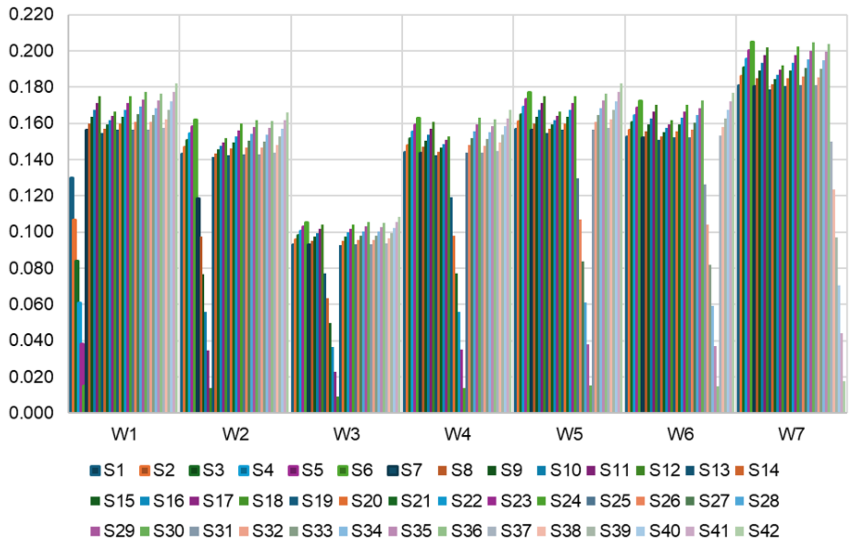
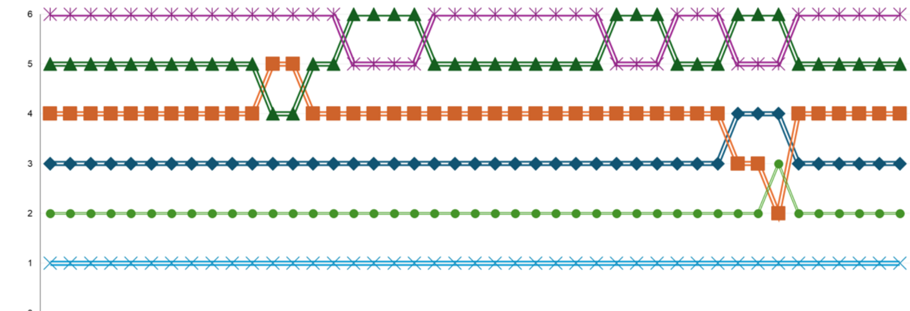


Figure 4. New weighting coefficient values of all criteria



	SET 0	SET 1	SET 2	SET 3	SET 4	SET 5	SET 6	SET 7	SET 8	SET 9	SET 10	SET 11	SET 12	SET 13	SET 14	SET 15	SET 16	SET 17	SET 18	SET 19	SET 20	SET 21
A1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
A2	4	4	4	4	4	4	4	4	4	4	4	5	5	4	4	4	4	4	4	4	4	4
A3	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	6	6	6	6	5	5	5
A4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	6	6	6
A6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

	SET 22	SET 23	SET 24	SET 25	SET 26	SET 27	SET 28	SET 29	SET 30	SET 31	SET 32	SET 33	SET 34	SET 35	SET 36	SET 37	SET 38	SET 39	SET 40	SET 41	SET 42
A1	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	3	3	3	3	3	3
A2	4	4	4	4	4	4	4	4	4	4	4	4	3	3	2	4	4	4	4	4	4
A3	5	5	5	5	5	5	6	6	6	5	5	5	6	6	6	5	5	5	5	5	5
A4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A5	6	6	6	6	6	6	5	5	5	6	6	6	5	5	5	6	6	6	6	6	6
A6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2

Figure 5. Sensitivity analysis results

Based on the results of the sensitivity analysis, it can be concluded that out of a total of 42 scenarios where the weights of the criteria were changed, 30 scenarios, i.e., 71.43%, did not affect the ranking of the alternatives. It can also be concluded that in all scenarios, only alternative A4 retained its first position and the change in weighting coefficients did not affect it. When observing the change in criterion 1 (S1–S6), no changes occurred and each alternative retained its position. The change in criterion 2 (S7–S12) led to changes for alternatives A2 and A3. For the change in criterion 3 (S13–S18), alternatives A2, A3, and A5 changed their positions. For the change in criterion 4 (S19–S24), each alternative retained its position. When changing criterion 5 (S25–S30), alternative A3 and alternative A5 swapped their positions. The most noticeable changes occurred for criterion 6 (S31–S36), with only alternative A4 retaining its position, while alternatives A1, A2, A3, A5, and A6 changed their positions. Finally, the change in criterion 7 (S37–S42) had no influence on changing the positions of the alternatives.

6 Comparative Analysis

After the sensitivity analysis, a comparative analysis was conducted, comparing the ranking results of alternatives obtained by the MARCOS method with the results obtained using the EDAS, WASPAS, and ARAS methods. For a more detailed analysis, the combinations of the OWCM method and the EDAS, WASPAS, and ARAS methods were used for determining the weights of the criteria. The same procedure was also conducted with the FUCOM (Full Consistency Method) for determining the weights of the criteria.

The results of the comparative analysis are shown in Figure 6.

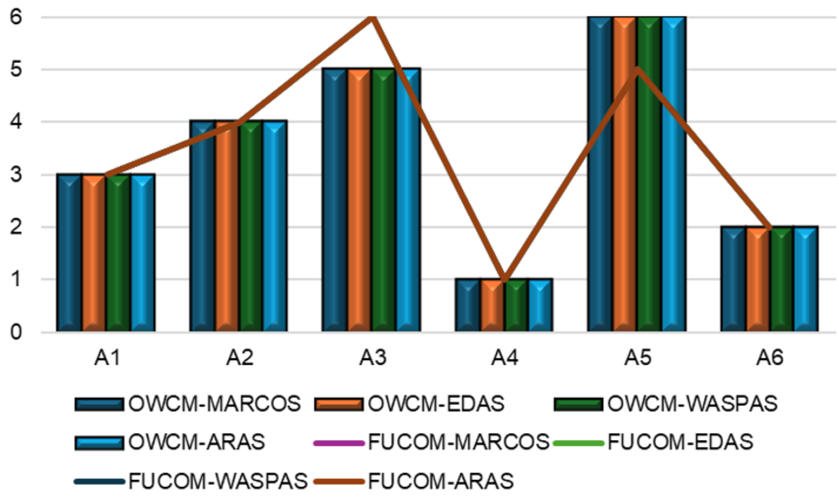


Figure 6. Comparative analysis results

The comparative analysis results show that the results obtained using the OWCM-MARCOS method are stable, indicating no changes. However, when the FUCOM method was used, certain changes in ranking occurred: alternative A5 shifted to fifth place, while alternative A3 shifted to sixth place. These changes are not significant, as the alternatives changed their rank by only one position. Alternatives A1, A2, A4, and A6 maintained their positions in each of the used combinations of multi-criteria decision-making methods.

7 Conclusion

This paper considers the determination of the optimal locations for the implementation of parcel lockers in the area of the Visoko distribution center, using MCDM methods. The focus is on the significance of the "last mile delivery" segment, which is recognized as the most demanding and expensive part of the logistics process, as well as on the opportunities offered by innovative solutions, such as parcel lockers, in improving the efficiency, cost-effectiveness, and sustainability of the delivery system. The development of e-commerce and changes in consumer habits have put pressure on traditional logistics models, which increasingly struggle to meet the challenges posed by the growing number of orders, traffic congestion, environmental constraints and rising user expectations. In this context, parcel lockers emerge as one of the most promising solutions as they allow users flexibility in collecting shipments, reduce the number of failed deliveries and contribute to reducing the burden on courier routes. Their implementation requires careful planning, particularly in terms of location selection, as only in this way can they achieve maximum benefits and user satisfaction. The methodological framework of the paper included the application of the OWCM method for determining the weighting coefficients of the criteria, and the application of the MARCOS method for ranking the alternatives. This combined approach enabled decision-making based on realistic and measurable indicators. The results of the model application have shown that alternative A4, i.e., the location on Arnautovića put (Suša Gas Station), represents the most suitable option for the installation of parcel lockers within the Visoko distribution center. This alternative ranked first and maintained its position across all scenarios in the sensitivity analysis, which confirms the stability and consistency of the results. The comparative analysis with other MCDM methods showed a high degree of agreement in the results, with minimal changes that had no significant impact on the top ranking of alternative A4.

The practical significance of this research is reflected in providing the X-Express company, as well as other logistics companies, with a methodological framework that enables them to make decisions about the layout of their logistics infrastructure. The implementation of parcel lockers in optimal locations contributes to improving the quality of service, reducing operating costs and increasing customer satisfaction, which ultimately enhances the competitiveness and sustainability of business. In addition, the broader application of such solutions has positive socio-environmental effects by reducing traffic congestion, emissions of harmful gases and noise in urban areas. Based on the above, it can be concluded that the objective of the paper has been successfully achieved. The proposed model, based on a combination of the OWCM and MARCOS methods, has proven to be a reliable tool for making decisions when selecting locations for parcel locker installation. By implementing an optimal location in the Visoko distribution center, the X-Express company can improve the quality of service and customer satisfaction, while also achieving long-term benefits regarding efficiency, costs, and business sustainability. Therefore, this paper represents not only an academic contribution but also a practical tool for the further development of modern logistics practice.

Author Contributions

Conceptualization, D.D. and Ž.S.; methodology, D.D. and Ž.S.; formal analysis, D.D. and Ž.S.; data curation, D.D. and Ž.S.; writing—original draft preparation, D.D. and Ž.S.; writing—review and editing, D.D. and Ž.S. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Acknowledgements

This paper is part of the research conducted within the project number 19.032/961-55/24 "Development of a location model for the installation of parcel terminals as an important factor in the sustainability of city logistics" approved by the Ministry of Scientific and Technological Development and Higher Education of the Republic of Srpska.

Conflicts of Interest

The authors declare no conflict of interest.

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