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A Multi-Criteria Analysis for E-Commerce Warehouse Location Selection Using SWARA and ARAS Methods

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Abstract: Selection of the optimal warehouse location represents a key strategic decision in modern logistics, particularly in the context of the rapid development of e-commerce and the increasing complexity of supply chains. The aim of this research is to identify the most favorable warehouse location within the urban area of Belgrade by applying multi-criteria decision-making (MCDM) methods. Specifically, a hybrid methodology that integrates the Step-wise Weight Assessment Ratio Analysis (SWARA) and Additive Ratio Assessment (ARAS) methods was employed to evaluate five real-world alternative locations based on eight relevant criteria. The considered criteria include: land cost, delivery time, infrastructure accessibility, labor availability, access to multiple modes of transport, site capacity, environmental conditions and regulatory compliance, as well as the competitiveness of the location itself. Criterion weights were determined through expert evaluation using the SWARA method, while the ARAS method was applied to rank the alternatives based on their normalized performance scores. The analysis indicated that the location in Batajnica (A1) is the most favorable, closely followed by the location on Pančevački Road (A3), owing to their balanced performance across economic, infrastructural, and operational dimensions. In contrast, the location in Kaluđerica/Leštane (A4) proved to be the least suitable, primarily due to poor infrastructure access and limited labor availability. The results confirm the applicability and effectiveness of combining SWARA and ARAS methods for solving complex decision-making problems involving multiple, often conflicting, criteria.

Keywords: Warehouse location selection; Logistics; MCDM; SWARA; ARAS; E-commerce

1 Introduction

In today's dynamic business environment, the optimization of logistics flows represents a fundamental pillar of organizational competitiveness. The accelerating growth of e-commerce, shrinking delivery lead times, and the rising complexity of supply chains have driven the need for increasingly sophisticated approaches to logistics infrastructure planning. Within this context, warehouses serve as critical distribution hubs that ensure supply chain continuity, balance supply and demand, consolidate shipments, and adapt to the specific needs of end users.

The selection of an optimal warehouse location plays a particularly strategic role, as it directly influences total transportation costs, delivery speed, market accessibility, and the environmental performance of the supply chain. This decision carries long-term implications for operational efficiency and financial outcomes, and as such, it is considered a high-priority strategic task in contemporary logistics management. Given the multidimensional nature of this challenge, the decision-making process requires a holistic evaluation of economic, infrastructural, environmental, and regulatory factors. Rapid urban development, increasingly stringent environmental regulations, and intensifying competition within the logistics sector further complicate this process, making the identification of optimal locations a complex and demanding endeavor. Recent trends also reflect a growing emphasis on sustainable logistics practices and green design principles in warehouse development. Increasing requirements for reducing CO_2 emissions, improving energy efficiency, and minimizing environmental impacts are now integral components of location selection criteria.

The digitalization of decision-making, supported by advanced software tools and analytical platforms, enhances transparency, consistency, and precision in the logistics site selection process. In line with these developments, there is a growing recognition of the value of MCDM methods in evaluating and selecting warehouse locations. These methods provide a structured framework for assessing a range of quantitative and qualitative factors, enabling decision-makers to achieve more objective, evidence-based, and robust conclusions.

This study applies a hybrid approach by combining two complementary MCDM techniques: SWARA, used to determine the relative importance of the criteria, and ARAS, employed to evaluate and rank the alternative locations. This methodological synergy enables a systematic and comprehensive assessment of candidate warehouse locations within the urban area of Belgrade, reflecting the complexity of today's market-driven distribution systems. The primary goal of the research is to identify the most suitable site for the construction of a warehouse that would meet the requirements of fast-paced e-commerce and modern distribution flows. The evaluation is based on clearly defined criteria encompassing cost efficiency, infrastructure accessibility, operational capability, and environmental sustainability.

The structure of this paper is organized as follows: following the introduction, a review of relevant literature is presented, followed by a detailed explanation of the applied methodology, case study analysis, discussion of the results, and finally, the conclusions and recommendations for future research.

2 Literature Review

In modern business environments, particularly under the influence of expanding e-commerce and globalization, logistics infrastructure has become a critical determinant of enterprise competitiveness. The warehouse, as one of the most vital nodes in the supply chain, ensures stability, flexibility, and timely delivery of products, especially in the context of cross-border flows and increasingly complex distribution networks [1, 2]. According to the study [3], choosing the location of a warehouse is considered a key strategic decision in the process of optimizing logistics systems. The placement of a warehouse plays a crucial role in the overall logistics process. Regardless of how efficiently internal operations are managed, a failure to deliver products on time from the warehouse can lead to customer dissatisfaction and potential loss of clientele. The study by Ulutaş et al. [4] evaluated five potential warehouse locations based on twelve different performance criteria. Similarly, Bairagi [5] proposed a novel MCDM model for warehouse location selection in supply chain. Therefore, selecting an appropriate warehouse location is a vital tactical and managerial decision in the automotive industry, given the strong link between strategically placed warehouses and an efficient logistics network. The developed model [6] was applied to determine the most suitable warehouse site for an automotive manufacturing company. Among the various approaches suggested for supporting location selection, the UTASTAR method proves effective in streamlining the decision-making process. It generates individual utility functions for each potential location, allowing for a structured evaluation and comparison based on multiple decision-making criteria. By reflecting the preferences of decision makers, UTASTAR facilitates the ranking of alternatives and helps justify the selection of the most appropriate warehouse location [7].

The study by Taletović [8] offers a comparative overview of more than ten different MCDM methods, including MARCOS (Measurement Alternatives and Ranking according to Compromise Solution), FUCOM (Full Consistency Method), WASPAS (Weighted Aggregated Sum Product Assessment), and ARAS, with applications in selecting warehouse equipment, locations, and sustainable logistics practices. In the study [9], the ARAS method was combined with the BWM for selection distribution center location selection, while the study [10] combines fuzzy AHP and TOPSIS to optimize internal warehouse layout. Comparative analyses of MCDM techniques in warehouse site selection can be found in studies [11, 12], applies the ARAS method to support decision-making on optimal facility locations within logistics networks. In the study [13], the author implemented Entropy and the ARAS method for determining the best warehouse location. On the other hand, in the study [14] the authors implemented fuzzy BWM for selecting warehouse location in Izmir. Cross-border logistics models and the significance of regional warehouse positioning in the context of growing e-commerce are addressed in study [15]. Spherical fuzzy extension of AHP-ARAS methods was applied by Gocer and Sener [16] in order to solve hub location problem. On the other hand, innovative decision-making approaches have been developed in study [17] to address the sustainable warehouse location selection problem by taking into account the boundaries of value changes and the aggregation of alternatives. These methods aim to enhance the evaluation process by incorporating both the variability in criteria importance and the collective performance of potential locations.

Regarding the criteria most frequently used for warehouse site selection, literature typically cites land and transportation costs, road infrastructure accessibility, proximity to markets and suppliers, as well as environmental factors such as CO_2 emissions, renewable energy potential, and regulatory compliance. In urban environments, additional factors include spatial accessibility, availability of micro-logistics, and delivery consolidation potential. In conclusion, the literature confirms that warehouse location selection is a multidimensional problem requiring precise and systematic evaluation methods.

The combined use of SWARA and ARAS methods offers a balanced approach that integrates expert judgment with formal analysis, enabling both flexibility and transparency in the decision-making process for warehouse location selection in complex logistics environments.

3 Methodology

To support rational decision-making in selecting the optimal warehouse location, this study employs MCDM methods. The warehouse location selection process involves a wide array of criteria that differ in nature, encompassing economic, infrastructural, social, and environmental aspects. Therefore, a methodological framework capable of simultaneously evaluating all these factors is essential (Figure 1).

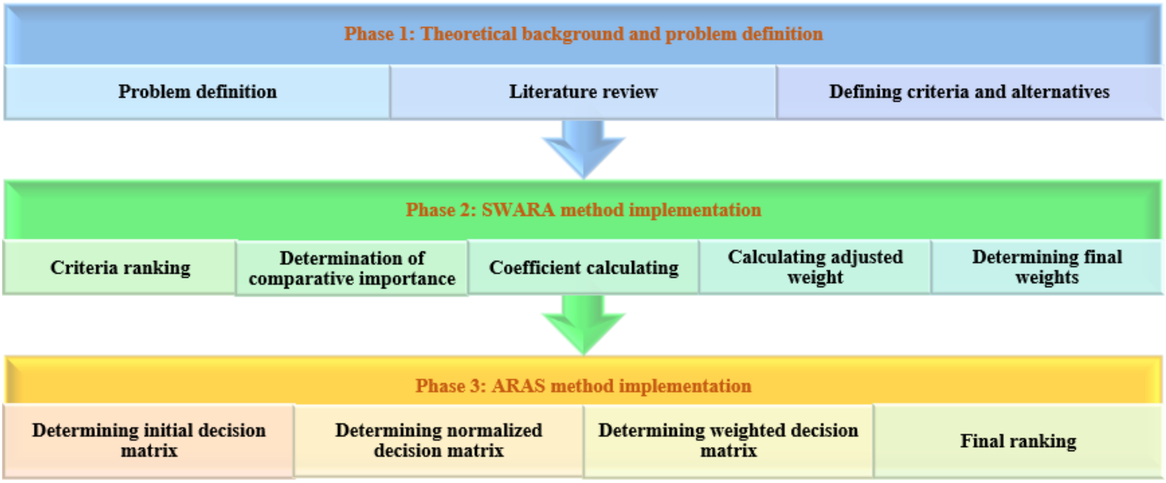

Figure 1. Methodology of the paper

For this purpose, the SWARA and ARAS methods were selected due to their ease of application, logical transparency, and ability to incorporate both quantitative and qualitative criteria. The SWARA method facilitates the determination of the relative importance of criteria based on expert judgment, while the ARAS method enables the evaluation and ranking of alternatives according to their degree of closeness to the ideal solution. By combining these two methods, a balance is achieved between subjective evaluation (expert-based weighting of criteria) and objective assessment of alternatives, making this approach particularly suitable for real-world logistics scenarios.

Such a methodological integration allows for a deeper understanding of the factors influencing decision-making and provides a robust framework for analyzing multi-criteria problems in the fields of logistics and supply chain management.

3.1 SWARA Method

The SWARA method is a qualitative approach used to precisely determine the significance of each criterion in the decision-making process. This method enables decision-makers, with the assistance of experts, to assign weights to the criteria based on their assessment of importance. The steps for implementing this method are outlined below [18].

Step 1: The criteria are ranked from the most important to the least important.

Step 2: For each criterion (C_j), its relative importance is determined in comparison to the preceding criterion (C_{j-1}), using a comparative importance coefficient (S_j).

$$S_j \leftrightarrow j+1 = \sum_{k=1}^{r} C_j \leftrightarrow j+1/r \tag{1}$$

Step 3: The coefficient (K_j) is then computed as follows:

$$K_j = \begin{cases} 1 & j=1 \\ S_j+1 & j>1 \end{cases} \tag{2}$$

Step 4: Next, the adjusted weight (q_j) for each criterion is calculated:

$$q_j = \left\{ \begin{array}{cc} 1 & j=1 \\ q_j - 1/K_j & j>1 \end{array} \right. \tag{3}$$

Step 5: Finally, the normalized weight for each criterion (W_j) is determined as the sum of all adjusted weights:

$$W_j = q_j / \sum_{k=1}^{m} q_j \tag{4}$$

3.2 ARAS Method

The ARAS method is a quantitative approach to multi-criteria decision-making that enables the ranking of alternative solutions based on their proximity to the ideal solution. This method allows decision-makers to evaluate each scenario by integrating all criteria and their weighted values into a single utility function. By comparing each alternative with a predefined ideal value, the ARAS method provides clarity in identifying the most favorable choice. The steps for applying this method are outlined below [19].

Step 1: Forming initial decision-making matrix with m alternatives and n criteria.

$$X = \begin{bmatrix} x_{01} & x_{02} & \cdots & x_{0n} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}, \quad i = 0, 1, \ldots, m, \quad j = 1, 2, \ldots, n \tag{5}$$

where, x_{0j} denotes the optimal value for criterion j. If x_{0j} is not known in advance, it is determined using the following equations for benefit and cost criteria:

$$x_{0j} = \max_i x_{ij}, \quad \text{for benefit} \tag{6}$$

$$x_{0j} = \min_i x_{ij}, \quad \text{for cost} \tag{7}$$

Step 2: Normalization of decision-making matrix - In the second step, the normalized decision matrix ($\bar{X}$), is formed, where the elements are denoted as $\bar{x}_{ij}$.

$$\bar{X} = \begin{bmatrix} \bar{x}_{01} & \bar{x}_{02} & \cdots & \bar{x}_{0n} \\ \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1n} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{x}_{m1} & \bar{x}_{m2} & \cdots & \bar{x}_{mn} \end{bmatrix}, \quad i = 0, 1, \ldots, m, \quad j = 1, 2, \ldots, n \tag{8}$$

The following equation is used to normalize benefit-type criteria:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{9}$$

Additionally, the following formulas are used to normalize cost-type criteria:

$$\bar{x}_{ij} = \frac{1}{x_{ij}^*}, \quad \bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{10}$$

Step 3: Formation of the weighted decision-making matrix - In this step, the normalizedweighted decision matrix ($\widehat{X}$) is formed.

$$\widehat{X} = \begin{bmatrix} \widehat{x}_{01} & \widehat{x}_{02} & \cdots & \widehat{x}_{0n} \\ \widehat{x}_{11} & \widehat{x}_{12} & \cdots & \widehat{x}_{1n} \\ \widehat{x}_{21} & \widehat{x}_{22} & \cdots & \widehat{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widehat{x}_{m1} & \widehat{x}_{m2} & \cdots & \widehat{x}_{mn} \end{bmatrix}, \quad i = 0, 1, \ldots, m, \quad j = 1, 2, \ldots, n \tag{11}$$

The elements of the normalized-weighted decision matrix are denoted as $\widehat{x}_{ij}$ and are calculated as follows:

$$\widehat{x}_{ij} = \bar{x}_{ij} \times w_j, \quad i = 0, 1, \ldots, m \tag{12}$$

Step 4: Calculation of the optimality function value for each alternative - In this step, the optimality function and the utility degree of each alternative are calculated. The optimality function for alternative i is defined as follows:

$$S_i = \sum_{j=1}^{n} \widehat{x}_{ij}, \quad i = 0, 1, \ldots, m \tag{13}$$

where, S_i represents the optimality function for alternative i. The highest value of S_i indicates the best alternative, while the lowest indicates the worst. The higher the value of S_i, the more useful the alternative is. The degree of utility for an alternative K_i is determined by comparing its utility function to the ideal alternative S_0. Based on the utility degree, prioritization of alternatives can be done. The degree of utility for an alternative is expressed as:

$$K_i = \frac{S_i}{S_0}, \quad i = 0, 1, \ldots, m \tag{14}$$

where, K_i represents the degree of utility for alternative i, which can range from 0 to 1. The higher the value of K_i, the more desirable the alternative.

Thanks to its ease of application, transparency, and clear interpretation of results, the ARAS method is suitable for solving complex decision-making problems. It is especially useful in situations where there is a need to balance multiple objectives and when the criteria are expressed using different scales. Due to its simple logic and the ability to apply it to both quantitative and qualitative data, ARAS has proven to be a reliable tool in the analysis and decision-making of logistics processes. The detailed steps for using this method are provided in the paper.

4 Case Study

The data used in this study were collected through a combination of expert evaluations and analysis of secondary sources. The values of alternatives for each criterion were obtained by analyzing real-world logistics locations in Serbia, taking into account factors such as proximity to major roadways, market accessibility, land prices, and labor availability. To ensure comparability across alternatives, the data were standardized and expressed on a uniform ordinal scale from 1 to 5. For benefit-type criteria (e.g., site capacity, regulatory compliance), higher values indicate more favorable characteristics, while for cost-type criteria (e.g., land costs, location competitiveness), the opposite applies. Since the selected criteria are not of equal importance, they were ranked by descending significance based on expert judgment and subsequently weighted using the SWARA method, as explained in the following section. After weighting, values were normalized in accordance with the requirements of the ARAS method, allowing for an objective ranking of alternatives based on their relative performance compared to the ideal solution. The process of criteria selection represents a critical step in any multi-criteria decision-making model, as it directly impacts the relevance and accuracy of the results. Based on a literature review [20, 21] and consultations with logistics professionals, a set of eight criteria was defined, covering economic, infrastructural, environmental, and operational dimensions. The criteria included in this study are as follows:

C1 - Land Cost: Land cost is one of the key factors in choosing a warehouse location, as it directly affects the overall investment budget in the early project phase. It varies depending on geographic location, proximity to urban zones, infrastructure development, and land-use planning. Given the typically large surface area required for warehouses and possible future expansion, this cost can represent a significant portion of the total investment. In this model, land cost is treated as a cost-type criterion (to be minimized), as lower land prices are considered more favorable for project feasibility, particularly in resource-constrained contexts.

C2 - Delivery Time: Delivery time is a critical metric in evaluating logistics efficiency, directly influencing end-user satisfaction. It depends on the location's connectivity and distance to final destinations, traffic conditions, and the potential for fast, reliable distribution. In this study, Belgrade is used as the reference point due to its role as the country's main consumption center. Locations that enable shorter and more reliable delivery times to Belgrade are considered more favorable and are scored higher. Thus, this is a benefit-type criterion.

C3 - Infrastructure Accessibility: This criterion assesses the quality and development of transport infrastructure near the site, including roads, access routes, and the ability to accommodate freight vehicles. Well-connected locations enable smoother logistics operations, reduce vehicle waiting times, and lower operating costs. This is considered a benefit-type criterion, as direct and efficient access improves logistical performance.

C4 - Labor Availability: The availability of skilled labor is essential for warehouse operations, including inventory management, picking, packing, and administration. Labor shortages can cause inefficiencies and increase operational costs. Areas with better access to labor offer greater flexibility in workforce planning and are considered more attractive. This is also a benefit-type criterion.

C5 - Multimodal Transport Access: Sites with access to multiple transport modes (road, rail, river, air) allow for more resilient and efficient distribution networks, reducing dependence on any single transport mode and enhancing supply chain flexibility. This criterion is treated as benefit-type, as increased transport options enhance the location's logistics value.

C6 - Site Capacity: When selecting the optimal location for constructing a warehouse facility, site capacity determines how effectively the location can support current and future logistics operations. This criterion includes the physical space available for goods storage, areas for handling activities (loading, unloading, shipment consolidation), adequate parking space for freight vehicles, as well as the potential for installing necessary logistics equipment and technology. In addition to existing capacity, this criterion also considers the site's potential for future expansion, i.e., the possibility of increasing warehouse space in line with business growth without relocating or incurring additional relocation costs. Locations that allow for phased construction, development of auxiliary facilities, or flexible infrastructure adaptation offer significant advantages for long-term business planning. This is treated as a maximization criterion, since locations offering greater physical capacity, better spatial organization, and expansion opportunities enable higher operational flexibility and market competitiveness.

C7 - Environmental Conditions and Degree of Regulatory Compliance: In today's business environment, sustainability and corporate social responsibility are increasingly valued. This criterion involves the assessment of a location's environmental impact, including noise emissions, air and water pollution, and conservation of natural resources. Beyond environmental effects, it also evaluates the level of compliance with applicable environmental, urban planning, and construction regulations. Locations that meet high environmental standards and are legally compliant with local and international regulations reduce the risk of legal barriers, penalties, and additional costs, thereby ensuring long-term investment security and sustainability. Therefore, environmental conditions and regulatory compliance are treated as a maximization criterion, locations with better environmental profiles and a higher level of legal compliance are evaluated as more favorable for long-term warehouse positioning.

C8 - Location Competitiveness: Location competitiveness refers to the intensity of existing competition in the immediate vicinity of the proposed warehouse site. Locations already surrounded by a large number of similar storage facilities, logistics centers, or distribution points may pose a challenge in terms of market positioning, as the presence of competitors increases pricing pressure, demands service differentiation, and complicates client acquisition. Conversely, locations with a lower concentration of similar facilities facilitate easier market entry, quicker user acquisition, and higher chances of achieving stable revenue without the need for significant investment in branding or aggressive marketing strategies. Such locations offer a competitive advantage by reducing pressure on logistics operations and financial performance. As such, location competitiveness is treated as a minimization criterion in this study.

On the other hand, five alternative locations (A1, A2, A3, A4, A5), representing real geographic points within the territory of Belgrade, were considered in this research. The selection of alternatives was based on prior spatial and infrastructural analysis, as well as current trends in the growth of e-commerce in urban and regional zones. Each alternative was evaluated against ten defined criteria, forming the initial decision matrix that serves as the basis for the analysis. The analyzed alternatives are:

Location A1 - Batajnica: Batajnica is considered a suitable location for warehouse development due to its excellent transport connectivity with the European Route E75, Batajnica Road, and the highway to Novi Sad. It enables efficient access to the municipality of Zemun and the rest of the city via the Pupin Bridge, avoiding the city center, which is advantageous for freight vehicles. Its distance from residential areas offers favorable conditions in terms of environmental criteria (e.g., low noise levels). However, despite its strong transport position, the location is far from urban zones with the most intensive deliveries, which may be a limitation for warehouses focused on fast last-mile delivery.

Location A2 - Krnješevci: Located directly along the E70 highway, Krnješevci offers strong distribution potential in multiple directions. The surrounding presence of similar facilities indicates an established logistics zone, advantageous for infrastructure and market acceptance. However, the presence of competition may drive up land prices and necessitate differentiation through service quality, technology, or design to remain competitive. This location is well-suited for warehouses requiring solid road connectivity, though it lacks direct rail access (more readily available in Batajnica). The availability of unused land presents an advantage for warehouses planned for phased development.

Location A3 - Pančevački Put: Situated on the border between Belgrade and Pančevo, this location lies along the Pančevački Road and near the E70 route. Its connection to Zrenjaninski Road and the bypass leading to the Pupin Bridge adds to its mobility. While it has good access to central Belgrade, potential issues arise from traffic congestion on the Pančevački Bridge, particularly during peak hours, which may complicate urban deliveries. This location is well-suited for warehouses serving eastern and northeastern flows of goods, with additional benefits from the availability of land for expansion.

Location A4 - Kaluđerica / Leštane: This site is located near the E75 highway and provides direct access to road transport within Belgrade and to international routes. Being relatively underdeveloped, it has significant potential for warehouse capacity development. However, recent accelerated urbanization has led to increased residential density, which may introduce limitations regarding noise, traffic frequency, and environmental standards. The location is favorable for warehouses requiring spatial flexibility and access to major roadways but should be approached with caution due to potential urban planning constraints.

Location A5 - New Belgrade (Block 66): This location is attractive due to its proximity to end-users — situated in a densely populated urban area, close to the E75 route and the Ada Bridge, which allows fast access to western and central parts of the city. It is ideal for warehouses requiring frequent last-mile deliveries. However, it is limited in terms of capacity expansion. Additionally, challenges related to noise and the visual integration of the facility into the existing urban architecture may increase design and construction costs. This site is best suited for urban warehouse concepts with limited scale and a strong focus on last-mile delivery.

After collecting all the criteria, defining the alternatives, and systematizing the supporting data, the initial decision matrix (Table 1) was created, and the analysis was conducted using the selected multi-criteria decision-making methods.

Table 1. Initial decision-making matrix

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
optimal	min	max	max	max	max	max	max	min
A1	3	3	4	1	3	4	1	2
A2	3	1	4	2	3	4	2	4
A3	3	4	1	4	2	1	5	3
A4	4	5	1	1	2	2	5	3
A5	4	2	4	4	2	2	1	2

The following chapter presents the results of applying the selected methods. Criteria weights were determined using the SWARA method, data normalization was performed according to the ARAS procedure, and finally, all alternatives were ranked. The results are presented through tables, charts, and corresponding interpretations, along with an analysis of their implications for selecting the optimal warehouse location.

5 Results and Discussion

This chapter presents the results of the analysis conducted using the SWARA and ARAS methods on the selected set of criteria and alternatives. Based on the collected data, the relative weights of the criteria were determined, the values were normalized, and utility coefficients were calculated for each of the evaluated locations.

The obtained results enabled the ranking of alternative locations in accordance with their overall performance, thereby identifying the most favorable site for warehouse construction.

5.1 SWARA Method Results

Table 2. Calculated criteria weights

Criteria	S_j	$K_j = S_j + 1$	Q_j	W_j
C1	–	1.00	1.000	0.195
C2	0.03	1.03	0.971	0.189
C3	0.27	1.27	0.764	0.149
C4	0.11	1.11	0.689	0.134
C5	0.32	1.32	0.522	0.102
C6	0.05	1.05	0.497	0.097
C7	0.37	1.37	0.363	0.071
C8	0.14	1.14	0.318	0.062
$\sum$			5.124	1.000

To determine the relative importance of the criteria, the SWARA method was applied. The process began with ranking the criteria according to their significance, where land cost (C1) was identified as the most important criterion, while environmental conditions and the degree of regulatory compliance (C7), along with location competitiveness (C8), were evaluated as the least influential criteria for warehouse site selection.

Following the ranking, the relative importance (S_j) of each criterion was assessed in relation to the preceding one on the list. Based on these values, correction coefficients ($K_j = S_j + 1$), relative weights (Q_j), and final normalized weights (W_j) were calculated. The assigned weights are presented in Table 2.

The obtained values clearly indicate that land cost (W_j=0.195) and delivery time (W_j=0.189) are the most influential criteria, exerting approximately three times greater impact on the decision-making process compared to location competitiveness (W_j=0.062) and environmental conditions (W_j=0.071), which hold the lowest relative importance in the overall location assessment.

5.2 ARAS Method Results

After determining the criterion weights using the SWARA method, the evaluation of alternatives was carried out using the ARAS method. In the first phase, the initial decision-making matrix was constructed, containing the evaluation values of all alternatives for each criterion, as presented in Table 1 of the previous chapter. Based on this matrix, the optimal criterion values (x_{0j}) were identified and are shown in Table 3.

Table 3. Optimal criteria values

	C1	C2	C3	C4	C5	C6	C7	C8
x_{0j}	3	5	4	4	3	4	5	2

To enable comparable evaluation, the criterion values were normalized in accordance with the ARAS method. For maximization-type criteria, normalization was performed by dividing the individual value of each alternative by the sum of all values for that criterion. This ensured that all values were expressed on a proportional scale and could be compared to one another. The normalized decision matrix is presented in Table 4, where A0 denotes the alternative with optimal values.

Table 4. Normalized decision-making matrix

	C1	C2	C3	C4	C5	C6	C7	C8
W_j	0.195	0.19	0.149	0.134	0.102	0.097	0.071	0.062
A0	0.18	0.25	0.22	0.25	0.20	0.24	0.26	0.21
A1	0.18	0.15	0.22	0.06	0.20	0.24	0.05	0.21
A2	0.18	0.05	0.22	0.13	0.20	0.24	0.11	0.10
A3	0.18	0.20	0.06	0.25	0.13	0.06	0.26	0.14
A4	0.14	0.25	0.06	0.06	0.13	0.12	0.26	0.14
A5	0.14	0.10	0.22	0.25	0.13	0.12	0.05	0.21

Table 5. Weighted decision-making matrix

	C1	C2	C3	C4	C5	C6	C7	C8
W_j	0.195	0.19	0.149	0.134	0.102	0.097	0.071	0.062
A0	0.04	0.05	0.03	0.03	0.02	0.02	0.02	0.01
A1	0.04	0.03	0.03	0.01	0.02	0.02	0.00	0.01
A2	0.04	0.01	0.03	0.02	0.02	0.02	0.01	0.01
A3	0.04	0.04	0.01	0.03	0.01	0.01	0.02	0.01
A4	0.03	0.05	0.01	0.01	0.01	0.01	0.02	0.01
A5	0.03	0.02	0.03	0.03	0.01	0.01	0.00	0.01

In the next step, the normalized values were weighted using the corresponding criterion weights obtained through the SWARA method. This resulted in the formation of the weighted decision matrix, presented in Table 5, which serves as the basis for further analysis. Subsequently, the optimality function (S_i) was calculated for each alternative as the sum of the weighted values. The resulting values are presented in Table 6.

Based on the calculated optimality function, utility coefficients (K_i) were determined, representing the relative ratio of each alternative's optimality function to that of the ideal alternative. Finally, all alternatives were ranked (Table 7) according to their utility coefficients, where a higher K_i value indicates a better position of the alternative in the overall evaluation.

Table 6. Optimality function of every alternative

Alternative	S_i
A0	0.22
A1	0.17
A2	0.15
A3	0.16
A4	0.14
A5	0.15

Table 7. Alternative ranking

Alternative	K_i	Rank
A1	0.74	1
A2	0.68	4
A3	0.72	2
A4	0.64	5
A5	0.69	3

Alternative A1 (Batajnica) demonstrated the best overall performance, with a utility coefficient of K_i=0.74, ranking first. This result indicates that A1 consistently performs well on key criteria, particularly in terms of land costs, infrastructure access, and site capacity, which have the greatest impact on the overall evaluation.

A3 (Pančevački Put) ranks second with K_i=0.72. Its high position is the result of excellent performance on labor availability and environmental conditions criteria, despite weaker infrastructure connectivity.

A5 (New Belgrade - Block 66) takes third place with K_i=0.69, owing to strong ratings on infrastructure access and labor availability, although environmental conditions and delivery time factors were rated slightly lower.

A2 (Krnješevci) is ranked fourth with K_i=0.68. While it has solid scores regarding land costs and infrastructure access, its poor performance on the delivery time criterion significantly impacted its overall ranking.

A4 (Kaluđerica/Leštane) occupies the last, fifth position with K_i=0.64. While it has excellent scores on environmental conditions and delivery time criteria, weaker values on infrastructure access and labor availability contributed to its lower overall ranking.

6 Conclusion

The selection of the optimal warehouse location is one of the most important strategic tasks in modern logistics, especially in the context of the growth of e-commerce and the demand for faster and more efficient deliveries. This research demonstrates the application of the SWARA and ARAS multi-criteria decision-making methods in the evaluation and ranking of alternative locations in the Belgrade area.

Based on the conducted analysis, alternative A1 (Batajnica) was ranked as the most favorable location for warehouse construction. This location achieved the highest utility coefficient, primarily due to favorable land costs, good infrastructure connectivity, and sufficient capacity for warehouse operations. The alternative A3 (Pančevački Put) follows, standing out for its favorable environmental conditions and labor availability, while A5 (New Belgrade) and A2 (Krnješevci) achieved solid, yet slightly lower results due to lower scores in delivery time and location competitiveness. The lowest-ranked alternative was A4 (Kaluđerica/Leštane), despite excellent environmental conditions, due to weaker infrastructure access and limited access to skilled labor.

The results obtained through the application of the mentioned methods confirm the advantages of the multi-criteria decision-making approach in complex logistical challenges. Systematic evaluation and weighting of criteria allowed for more objective ranking of alternatives and reduced the impact of subjective assessments, contributing to more transparent and reliable decision-making.

The practical implications of this research are seen in the potential application of the developed model in real conditions, especially for companies planning to expand warehouse capacities or optimize distribution networks in urban areas. The application of the methodology enables companies to quantitatively evaluate multiple factors simultaneously, increasing the likelihood of selecting a location that will contribute to long-term operational efficiency and competitiveness.

For future research, it is recommended to expand the model by including additional factors such as maintenance costs, the impact of seasonal fluctuations on distribution flows, as well as analyzing the impact of different e-commerce growth scenarios on warehouse capacity requirements. Additionally, the application of fuzzy versions of the ARAS method or integration with simulation techniques could further improve the precision and flexibility of the model.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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