

STRATEGIC SELECTION OF A LOGISTICS CENTER LOCATION USING A HYBRID MCDM MODEL BASED ON PIPRECIA AND SAW METHODS: AN EMPIRICAL STUDY

DOI: 10.5937/EMC26087R

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ABSTRACT

The strategic selection of a logistics center location represents a complex multi-criteria problem involving economic, infrastructural, and socio-geographical factors. This paper applies a hybrid MCDM model based on the PIPRECIA and SAW methods to evaluate and rank potential locations in the Republic of Serbia. A set of ten criteria was defined, and weight coefficients were determined using the PIPRECIA method via direct and inverse procedures. The stability of the obtained weights was confirmed using Spearman's rank correlation coefficient ($\rho=0.723724$). The final ranking was performed using the SAW method for three alternative locations: Belgrade, Smederevo and Požarevac. The results indicate that utility infrastructure C_4 , proximity to the highway C_2 , and labor availability C_3 are the most important criteria. Belgrade was identified as the optimal location (score 4.26), ahead of Smederevo (3.86) and Požarevac (3.69). The research confirms that the hybrid PIPRECIA-SAW model represents an efficient and transparent decision-support tool for logistics center site selection at the regional level in Serbia.

Keywords: PIPRECIA, SAW, MCDM, Logistics Center, Strategic Planning

INTRODUCTION

Global digitalization and the widespread expectation of same-day delivery have pushed logistics beyond its traditional role as a support function, elevating it into a core source of competitive advantage. As Farahani & Hekmatfar (2009), Kayikci (2010), and the City of Požarevac (2021) have observed, choosing a location for a new logistics center is no longer simply about finding available land; it is a complex investment decision with long-term strategic consequences. An incorrect choice can lock a company into permanently high operational costs, restrict access to skilled labor, and degrade service levels, all of which directly weaken its market position. The problem of selecting an optimal location is marked by considerable uncertainty and the presence of many conflicting factors. As (Garić et al., 2024) point out, sites with excellent transport links often come with high rental and tax costs, while fiscally attractive areas may suffer from poor infrastructure or a shortage of specific labor profiles. For this reason, the academic literature classifies this type of problem as a typical multi-criteria decision-making (MCDM) problem (Hwang & Yoon, 1981; Triantaphyllou, 2000; Zavadskas et al., 2014). The aim of this paper is to implement a hybrid mathematical model that combines the subjective expertise of decision-makers with objective ranking methods. The research focuses on ten key criteria covering economic, infrastructural, and socio-geographical aspects for the strategic selection of a logistics center location in the Republic of Serbia (Mihajlović et al., 2019). Through the application of the PIPRECIA and SAW methods, the paper seeks to establish a transparent and replicable decision-making process that minimizes cognitive biases and provides an objective foundation for the final selection among three considered alternatives - the cities of Belgrade (henceforth abbreviated as A), Smederevo (B), and Požarevac (C). Similar hybrid approaches

integrating criteria weighting and ranking have also been used in other studies of logistics facilities in Serbia (Pajić et al., 2024).

THEORETICAL FRAMEWORK

The PIPRECIA Method (Determining Criterion Weights)

Developed by (Stanujkić et al., 2025), the PIPRECIA method responds to the need for simpler yet equally reliable alternatives compared to traditional approaches such as the Analytic Hierarchy Process (AHP). One of its main advantages is that it does not require decision-makers to carry out an excessive number of pairwise comparisons. With ten criteria, as in the present study, such a large number of comparisons often leads to logical inconsistencies and fatigue (Saaty, 1990; Rezaei, 2015; Govindan, et al., 2016; Stanujkić et al., 2025).

The methodological procedure is carried out in two key phases, illustrated in Figure 1 (Algorithm of the hybrid PIPRECIA-SAW model):

- Direct procedure: The decision-maker ranks the criteria and assigns to each a value s_j , which represents the importance of a given criterion relative to the previously ranked one. If the criterion is more important $s_j > 1$; if it is less important, $s_j < 1$. Based on these values, coefficients k_j are calculated, followed by recursive values q_j , which form the basis for the normalization of weights w_j .
- Inverse (reverse) procedure: This step is essential for validating the model. The process is repeated starting from the last ranked criterion and moving backward to the first. Weights w'_j are calculated from this reverse run. The final weight coefficients are obtained as the arithmetic mean of the values from both directions. This approach allows for the detection of so-called "resistance" in decision-making - if the differences between direct and inverse weights are too large, this indicates that the decision-maker lacks a clear hierarchy of priorities, requiring a revision of the model. Stability is further confirmed by Spearman's rank correlation coefficient (ρ), with values close to one indicating a high level of consistency (Conover, 1999; Well & Myers, 2003).

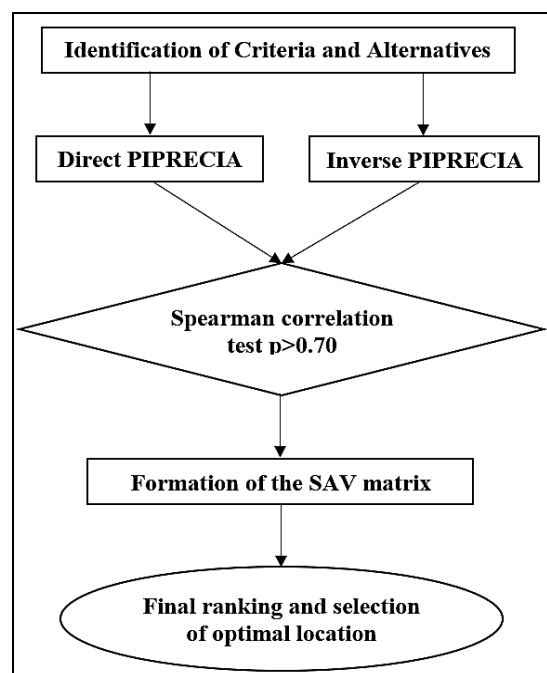


Figure 1: Algorithm of the hybrid PIPRECIA-SAW model

The SAW Method (Ranking Alternatives)

Once the criterion weights have been precisely determined, the evaluation of alternatives proceeds using the Simple Additive Weighting (SAW) method. Although it is among the oldest MCDM methods (Fishburn, 1967; MacCrimmon, 1968), SAW remains widely used in engineering practice due to its intuitive nature and mathematical transparency (Afshari et al., 2010; Özcan et al., 2011). The SAW implementation consists of three steps:

- Forming the decision matrix: The performance of each location (alternative) with respect to each criterion is entered.
- Normalization: Since criteria may have different units of measurement or different natures (e.g., costs to be minimized versus profits to be maximized), all values are scaled to the interval $[0, 1]$. In this study, because all evaluations were assigned on a unified scale (1-5), the focus is on linear transformation.

- Aggregation: The total score for each alternative is obtained by summing the products of the normalized score and the criterion weight coefficient.

The final score represents a weighted sum that allows us to clearly identify which location best satisfies the stated strategic goals. The SAW method was chosen for this research because it enables the decision-maker to see clearly the contribution of each individual criterion to the overall score of an alternative, thereby facilitating discussion and final acceptance of the solution.

ANALYSIS AND CALCULATIONS

The first step in applying the PIPRECIA method was to define a set of ten criteria C_1 - C_{10} covering all aspects of logistics operations and three alternatives, and as shown in Tables 1 and 2.

Table 1: Defined criteria for logistics center site selection with descriptions

Criterion	Description
C_1 Land costs	Total purchase or lease costs of the plot, including associated fees
C_2 Proximity to highway	Distance from the site to key transport corridors (e.g., E-75)
C_3 Labor availability	Presence of qualified personnel and proximity to populated areas
C_4 Utilities (electricity, water, gas)	Level of site equipment (connections for electricity, gas, water)
C_5 Local taxes and incentives	Administrative costs and available investment incentives
C_6 Proximity to major customers	Geographic distance from key distribution points
C_7 Environmental regulations	Stringency of environmental norms and construction restrictions
C_8 Site security	Risk level from theft, natural disasters, or vandalism
C_9 Future expansion potential	Availability of adjacent plots for future expansion
C_{10} Telecommunication quality	Quality and availability of fiber optic and 4G/5G networks at the site

Table 2: Defined alternatives for logistics center site selection with descriptions

Alternatives	Description
Belgrade (A)	Regional center of the Republic of Serbia
Smederevo (B)	Municipality and town on the Danube, eastern part of the Republic of Serbia
Požarevac (C)	Municipality and town in the eastern part of the Republic of Serbia

The decision-maker first ranked the criteria in order of importance and then determined the relative significance s_j of each criterion relative to the previous one. In the direct procedure (Table 3), the sum of recursive values was 9.973, while in the inverse procedure (Table 4) carried out to verify precision the sum reached 11.241. In the direct procedure the first criterion C_1 is taken as the base with a value of $k_1=1$. For each subsequent criterion, the coefficient k_j was calculated according to Formula (1):

$$k_j = 2 - s_j \quad (1)$$

Based on this, the weights w_j were calculated by normalization: $w_j = q_j / \sum q_j$. In this direction, criterion C_4 (Utilities) emerged as the most important with a weight of 0.123, while C_{10} (Telecommunication quality) was the least important with a weight of 0.070.

Inverse procedure (Table 4) to verify stability, the procedure was repeated in the opposite direction, starting from C_{10} and moving to C_1 . In this step, the sum of recursive values q'_j was 11.241. The weights obtained in this step (w'_j) showed slight variation. Criterion C_4 (Utilities) again ranked highest with a weight of 0.117, while C_9 (Future expansion potential) was the least important with a weight of 0.077. were determined using Formula (2):

$$q_j = \frac{q_{j+1}}{k_j} \quad (2)$$

Table 3: Weight coefficient calculation for the direct procedure of the PIPRECIA method

Criterion	s_j	$k_j=2-s_j$	$q_j=q_{j-1}/k_j$	w_j	rank
C ₁ Land costs		1.00	1.000	0.100	6
C ₂ Proximity to highway	1.05	0.95	1.053	0.106	4
C ₃ Labor availability	1.05	0.95	1.108	0.111	3
C ₄ Utilities (electricity, water, gas)	1.10	0.90	1.231	0.123	1
C ₅ Local taxes and incentives	0.80	1.20	1.026	0.103	5
C ₆ Proximity to major customers	1.15	0.85	1.207	0.121	2
C ₇ Environmental regulations	0.75	1.25	0.966	0.097	7
C ₈ Site security	0.95	1.05	0.920	0.092	8
C ₉ Future expansion potential	0.80	1.20	0.766	0.077	9
C ₁₀ Telecommunication quality	0.90	1.10	0.697	0.070	10
			9.973	1.000	

Table 4: Weight coefficient calculation for the inverse procedure of the PIPRECIA method

Criterion	s'_j	$k'_j=2-s'_j$	$q'_j=q'_{j+1}/k'_j$	w'_j	rank*
C ₁₀ Telecommunication quality		1	1.000	0.089	9
C ₉ Future expansion potential	0.85	1.15	0.870	0.077	10
C ₈ Site security	1.15	0.85	1.023	0.091	8
C ₇ Environmental regulations	1.20	0.80	1.279	0.114	2
C ₆ Proximity to major customers	0.80	1.20	1.066	0.095	6
C ₅ Local taxes and incentives	1.10	0.90	1.184	0.105	5
C ₄ Utilities	1.10	0.90	1.316	0.117	1
C ₃ Labor availability	0.90	1.10	1.196	0.106	4
C ₂ Proximity to highway	1.05	0.95	1.259	0.112	3
C ₁ Land costs	0.80	1.20	1.049	0.093	7
			11.241	1.000	

Final weights (Table 5) were obtained as the arithmetic mean of both procedures, thereby neutralizing potential extremely subjective assessments. The key weights favor C₄ (Utilities) with 0.115, C₂ (Proximity to highway) with 0.109, C₃ (Labor availability) with 0.109, and C₆ (Proximity to major customers) with 0.108. The least important criterion is C₉ (Future expansion potential) with a weight of 0.077. Final weights are calculated using Formula (3):

$$\bar{\omega}_j = \frac{\omega_j + \omega'_j}{2} \quad (3)$$

Table 5: Comparative presentation of weights and calculation of final weights

Criterion	$(w_j + w'_j)/2$	rank(fin)
C ₁ Land costs	0.097	7
C ₂ Proximity to highway	0.109	2
C ₃ Labor availability	0.109	3
C ₄ Utilities (electricity, water, gas)	0.115	1
C ₅ Local taxes and incentives	0.104	6
C ₆ Proximity to major customers	0.108	4
C ₇ Environmental regulations	0.105	5
C ₈ Site security	0.092	8
C ₉ Future expansion potential	0.077	10
C ₁₀ Telecommunication quality	0.079	9
	0.995	

To confirm that the subjective assessments were not contradictory, Spearman's rank correlation coefficient (ρ). was applied (Table 6). Rankings were performed for both sets of weights (w_{ji} i w'_j). Some deviations were observed, particularly for C₇ (Environmental regulations) with a squared difference of 25 and C₆ (Proximity to major customers) with a squared difference of 16. The resulting

Spearman coefficient ($\rho=0.723724$), confirms that the model is ready for the ranking phase of alternatives. The calculation was carried out according to Formula (4):

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \quad (4)$$

Table 6: Rank difference matrix and calculation of Spearman's correlation coefficient (ρ)

Criterion	rank	rank*	rank - rank*	(rank - rank*) ²
C ₁ Land costs	6	7	-1	1
C ₂ Proximity to highway	4	3	1	1
C ₃ Labor availability	3	4	-1	1
C ₄ Utilities (electricity, water, gas)	1	1	0	0
C ₅ Local taxes and incentives	5	5	0	0
C ₆ Proximity to major customers	2	6	-4	16
C ₇ Environmental regulations	7	2	5	25
C ₈ Site security	8	8	0	0
C ₉ Future expansion potential	9	10	-1	1
C ₁₀ Telecommunication quality	10	9	1	1
Sum:				46

In the second part of the analysis the SAW method (Table 7) was applied to the three potential locations Belgrade (A), Smederevo (B), and Požarevac (C), using scores on a scale from 1 to 5. Figure 2 presents a comparative overview of the importance of the alternatives (radar chart of final weights) for all alternatives. Based on the results, we can conclude that alternative A (Belgrade) performs best, followed by alternative B (Smederevo), with alternative C (Požarevac) ranking third.

Table 7: Decision matrix with alternative scores (A, B, C) by criterion and SAW ranking results

Criterion	(w _j +w _j [*])/2	A (Belgrade)	B (Smederevo)	C (Požarevac)
C ₁ Land costs	0.097	5	4	2
C ₂ Proximity to highway	0.109	4	4	4
C ₃ Labor availability	0.109	5	3	4
C ₄ Utilities (electricity, water, gas)	0.115	5	5	5
C ₅ Local taxes and incentives	0.104	3	4	3
C ₆ Proximity to major customers	0.108	4	3	4
C ₇ Environmental regulations	0.105	3	3	3
C ₈ Site security	0.092	5	5	4
C ₉ Future expansion potential	0.077	4	4	5
C ₁₀ Telecommunication quality	0.079	5	4	3
Sum:		4.26	3.86	3.69
rank		1	2	3

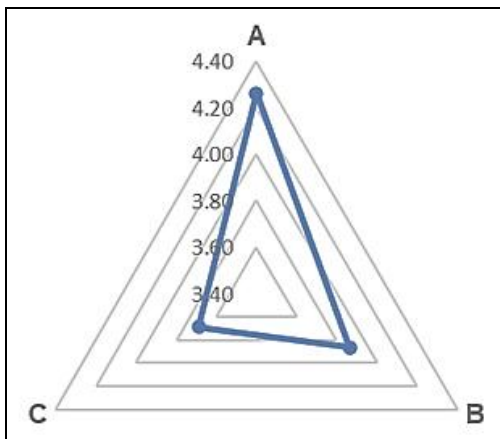


Figure 2: Comparative overview of alternative importance (Radar chart of final weights)

FINDINGS & DISCUSSION

Model stability - Spearman's rank correlation coefficient between the rankings obtained from the direct and inverse procedures is $\rho=0.724$. Although this value is not extremely high (close to 1), it falls within the range of acceptable consistency for subjective assessments in MCDM procedures (Conover, 1999; Well & Myers, 2003). The deviations are most pronounced for criteria C₇ (Environmental regulations) and C₆ (Proximity to major customers), as can be seen in Table 6.

These two criteria evidently introduce greater uncertainty for the decision-maker environmental regulations can be either a constraint or an incentive, while proximity to customers may be valued differently depending on whether the center's function is distributive or transit. Despite these deviations, the overall correlation is sufficiently high to justify using the average weights. Ranking of alternatives - based on the final weights and the scores in Table 6, the SAW method produced the following order: first place belongs to alternative A (Belgrade) with a total score of 4.26, followed by alternative B (Smederevo) with 3.86, and finally alternative C (Požarevac) with 3.69. The difference between the first- and second-ranked locations is 0.40 points, which is quite substantial on a 1-5 scale. Belgrade leads due to excellent scores for land costs (5), labor availability (5), infrastructure (5), security (5), and telecommunication quality (5). Smederevo has somewhat lower scores for labor (3) and proximity to customers (3), while Požarevac lags primarily because of higher land costs (2) and lower telecommunication quality (3). Interestingly, all three alternatives received the maximum score of 5 for criterion C_4 (Utilities), because basic utility connections are not a differentiating factor in this district. In contrast, land costs C_1 and telecommunication quality C_{10} proved to be key differentiators. Compared to similar studies in Serbia (Pajić et al., 2024), the obtained results confirm that regional centers (Belgrade) have an advantage over smaller municipalities when the SAW method is applied with a larger number of criteria. However, unlike some earlier works that favored locations solely based on transport accessibility, here human resources and security also played a significant role. Strategic planning of logistics centers in Serbia has become a full-fledged multi-criteria problem.

CONCLUSIONS AND IMPLICATIONS

This study aimed to apply a hybrid MCDM model based on the PIPRECIA and SAW methods for the strategic selection of a logistics center location in the Republic of Serbia. Based on the conducted analysis, the following conclusions can be drawn:

- The hybrid PIPRECIA-SAW model proved to be operationally feasible and transparent as a decision-support tool. The decision-maker successfully ranked ten criteria and assigned them weights without the need for a large number of pairwise comparisons. The Spearman coefficient of 0.724 confirms acceptable stability of the assessments, despite individual deviations for environmental and market criteria.
- The obtained weights show that under the conditions of the Republic of Serbia, the most important criteria are utility infrastructure (C_4), proximity to the highway (C_2), and labor availability (C_3). Together, these factors form the foundation for successfully positioning a logistics center. On the other hand, future expansion potential C_9 and telecommunication quality C_{10} received the lowest weights, which can be interpreted either as an assessment that these conditions are already satisfied at all locations, or as a short-term orientation on the part of the decision-maker.
- The SAW method determined that Belgrade (alternative A) is the highest-ranked location, ahead of Smederevo (B) and Požarevac (C). Belgrade achieves its advantage through balanced high scores for land costs, labor, infrastructure, and security. Smederevo and Požarevac lag primarily in the areas of human resources and telecommunications.

The research has certain limitations. First and foremost, this is a case study referring to only three alternatives. Generalizing the conclusions to other regions would require repeating the procedure with locally adapted criteria and a larger number of decision-makers. Additionally, the scores in the SAW matrix were given on an ordinal 1-5 scale, which is practical but does not constitute interval measurement. Future research could extend the model in several directions:

- Including a larger number of decision-makers and applying aggregation techniques (e.g., copula methods);
- Using fuzzy extensions of the PIPRECIA and SAW methods to handle uncertainty;
- Comparing the results with other MCDM methods (e.g., TOPSIS, PROMETHEE, ELECTRE); and
- Conducting a sensitivity analysis by varying the weights of the most important criteria.

In practical terms, the results provide a useful framework for local governments and investors in the Republic of Serbia. The recommendation is that when negotiating logistics center locations, special attention should be paid to improving conditions at locations Smederevo (B) and Požarevac (C), particularly regarding labor availability and telecommunications infrastructure, so that they can become more competitive relative to Belgrade (A).

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