APPLICATION OF SWARA AND TOPSIS METHOD FOR LOCATION SELECTION OF LOGISTICS CENTER IN ULAANBAATAR

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Abstract: Selecting the most suitable location for a logistics center is crucial for optimizing supply chain operations. This study employs an integration of the Stepwise Weight Assessment Ratio Analysis (SWARA) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods to evaluate and determine an appropriate location for a logistics center near Ulaanbaatar, Mongolia. The research responds to the increasing demand for effective logistics infrastructure in Mongolia, particularly in light of urbanization and expanding trade. By merging subjective expert evaluations with a comprehensive multi-criteria decision-making framework, this paper seeks to deliver a well-rounded approach to location selection. The synergistic application of SWARA and TOPSIS offers a systematic and objective process for identifying the optimal logistics center location, while considering transportation, infrastructure, cost, and environmental impacts.

Keywords: Logistics center, location selection, SWARA, TOPSIS

1. INTRODUCTION

The location of the logistics center has a major impact on transportation expenses, efficiency of operations, and success of logistics services as a whole. In Mongolia, Ulaanbaatar is a rapidly urbanizing city and is in need of logistics infrastructure, which has resulted from increasing trade and industrial needs from the country. With the wide geographical area of Mongolia, coupled with the low infrastructure facility outside Ulaanbaatar, it is quite difficult to select an appropriate location for establishing a logistics center. To select a suitable location for logistics centers, many quantitative and qualitative criteria must be considered in decision process such as investment cost, climate condition, resource availability, possibility of expansion, transportation availability, human resources, proximity to suppliers, and closeness to demand market, etc [1-3]. Therefore, logistics center location selection can be seen as a multi-criteria decision making (MCDM) problem.

This paper presents a hybrid approach combining SWARA, subjective method for criterion weighting, and TOPSIS-an objective method for alternatives ranking according distance from ideal solutions. This combination allows a holistic evaluation of prospective sites based on qualitative and quantitative criteria. The rest of the paper is organized as following sections. Section 2 reviews the basic concepts of MCDM, SWARA and TOPSIS. Section 3 proposes a combined approach. The proposed approach is applied to solve the real case of Ulaanbaatar in Section 4. Finally, conclusions are made in Section 5.

2. LITERATURE REVIEW

2.1 Location Selection and MCDM

A logistics center is defined by EUROPLAT FORMS EEIG as "*the hub of a specific area where all the activities relating to transport, logistics and goods distribution – both for national and international transit – are carried out, on a commercial basis, by various operators*" [1]. It is also called with different names such as "freight village", logistic base", "transport center" and "logistic village" in the literature. Logistics centers hold several facilities inside for storing, handling, clearing, reassembling disassembling, quality control of goods, providing accommodation and social services.

A wrong decision will affect firm operations and costs negatively. An optimal selection will decrease the costs (mainly transportation costs) and traffic problems; and it will increase performance, competitiveness and profitability [4, 5]. There are several methods used for the selection of a logistics center. These can be categorized as mathematical methods, financial methods, simulation methods and multi-criteria decision making methods. Due to involving various different factors, the selection of logistics center is a multi-criteria decision-making (MCDM) problem thus it needs to consider quantitative and qualitative criteria together [6].

The decision problems for location selections commonly follow the steps below [7]:
Step 1: Define the criteria for assessing alternatives.
Step 2: Calculate the weights of criteria
Step 3: Determine alternatives
Step 4: Assess the alternatives using the criteria found in Step 1, then give a decision for the most suitable alternative.

The multi-criteria decision-making methods are commonly used methods such as Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), fuzzy TOPSIS, Elimination and Choice Expressing Reality (ELECTRE) and fuzzy AHP due to the fact that logistics center selection problems involve various factors to be accounted.
Ghoseiri and Lessan [8] used the fuzzy AHP and ELECTRE methods for assessing 5 logistics center location alternatives. Farahani et al. [9] reviewed the studies about location selection problems involving multiple criteria under three groups; bi-objective, multi-objective and multi-attribute problems. They presented a list of criteria used in the literature.
Rao et al. [10] had worked on the CLC selection problem in terms of sustainability. They used a fuzzy multi attribute decision making model and three groups of criteria representing sustainability dimensions (economic, environmental and social) for the assessment of logistics center alternatives. Pham et al. [11] developed a Fuzzy-Delphi-TOPSIS combined model to select a logistics center in Vietnam from three alternatives; North Hanoi, Danang city, Provinces northeast of Ho Chi Minh City. They found that freight demand, access to market, production area, customers, and transportation costs are given the most importance among 14 criteria.

The selection of SWARA and TOPSIS for this study is motivated by their mutual strengths. SWARA offers a formal yet adaptive method to gainexpert opinion and assign weights to criteria in a balanced way without the big pairwise comparisons of AHP. TOPSIS, on the other hand, orders alternatives objectively on the basis of proximity to the ideal and negative-ideal solutions, hence intuitive and computationally efficient. Compared to more complex models like ELECTRE or ANP, hybrid SWARA-TOPSIS is easier to implement in real-life examples, such as in the case of emerging economies like Mongolia.

2.2 Step-wise Weight Assessment Ratio Analysis (SWARA)

The SWARA consists of simple, step-by-step procedure developed by Zavadskas et al. in 2012 in determining the relative importance of criteria in a decision-making process. Expert judgments are made on the importance of each criterion in a progressive ranking exercise. These rankings are transformed into weights representing the extent to which each criterion is important to a decision in question.

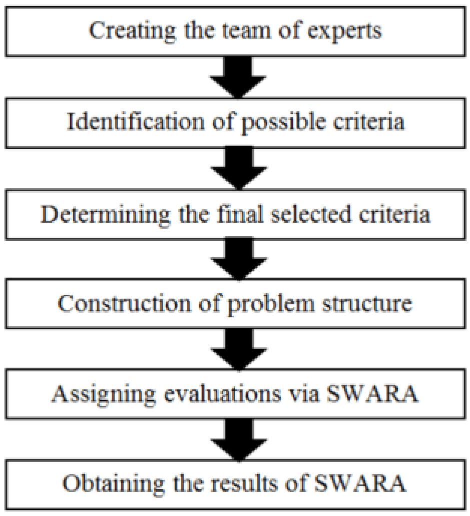

Fig.1 Methodology for SWARA

In SWARA the experts in the respective field has a very important role to play in determining the weights of the selected criteria. The expert uses his own implicit knowledge to rank the suppliers. Also, each expert can choose the importance of each criteria [12]. Once analyzed, the expert can reach on a solution giving the most important criteria to rank higher than the others. The main attraction of this method is that it has the ability to estimate the expert's opinion about the importance ratio of the criteria in the process of weight determination. The SWARA is simple, means that experts can easily work together as a team [12]. Compared with the analytic hierarchy process (AHP), the analytic network process (ANP) is flexible, i.e., it is easy to draw conclusions for issues where priorities and weights may vary depending on company policies. In addition, the SWARA method is simple and straightforward, and experts can easily collaborate. The main advantage of this method in decision-making is that for some issues, priorities are determined based on company or national policies, and there is no need to evaluate ranking criteria

2.3 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is an often used MCDM technique that ranks alternatives from the best to the worst by postulating the distance of these alternatives in regard to their "ideal" and "negative ideal" solutions. The ideal solution being the best circumstance that can be achieved, and the negative ideal solution-the worst that can be imagined. The alternatives are then ranked based on their relative closeness to the ideal solution as can be calculated through Euclidean distance measure from both solutions.
TOPSIS is an MCDM evaluation method introduced in 1992. The basic principle of the method is that the selected alternative must have the shortest distance to the ideal solution and the farthest distance from the negative-ideal solution [13]. The TOPSIS method has a goal-based approach [14]. The analysis results are evaluated based on their similarity to the ideal solution. For an option which is more similar to the ideal solution has the higher rank compared to the

option which is less similar to ideal solution. The method compares a set of alternatives by determining the weight of each criteria.

The TOPSIS method allows trade-offs between criteria, where a poor result in one criterion can be negated by a good result in another criteria. [15]

The steps in the TOPSIS method are as follows:

1. **Decision Matrix Construction:** A decision matrix is constructed where each alternative (location) is evaluated against each criterion.
2. **Normalization of the Matrix:** To ensure comparability, the values are normalized (using a vector normalization method).
3. **Ideal and Negative Ideal Solution:** The best (ideal) and worst (negative ideal) values for each criterion are determined.
4. **Distance Calculation:** The Euclidean distance from each alternative to the ideal and negative ideal solutions is calculated.
5. **Ranking of Alternatives:** The alternatives are ranked based on their proximity to the ideal solution. The alternative closest to the ideal solution is ranked first.

Limitations of SWARA and TOPSIS

Even though both SWARA and TOPSIS are strong, they have their own weaknesses. SWARA is very much dependent on the judgment of experts, which makes it subjective and prejudiced to some extent. The technique believes that expert rankings represent the relative importance of criteria accurately, which is not always true. TOPSIS, in turn, believes linear relationships between criteria and alternatives, which could be too simplistic for representing complex interdependencies. It also ignores correlations between criteria. Theawareness of such limitations is necessary to frame findings and defend the selection of methodology.

2.4 CASE STUDY: Location Selection in Ulaanbaatar

As a study area, we choose Ulaanbaatar city in Mongolia which is a land-locked country in the North-East Asia bordering China with 4.673 km in the south and Russian Federation with 3485 km in the north. The total territory of the country is 1.566 million square kilometers making approximately 1 square kilometers per 1.6 persons and 18th largest country in the world. Ulaanbaatar, the capital city of Mongolia, is the economic, cultural and political center of the country, with numerous tourist attractions and a wide variety of recreational activities. The city is divided into 9 districts and 122 districts. Ulaanbaatar is located on the Tuula River and is surrounded by four sacred mountains, with dense pine forests on the northern slopes and vast grasslands on the southern slopes.

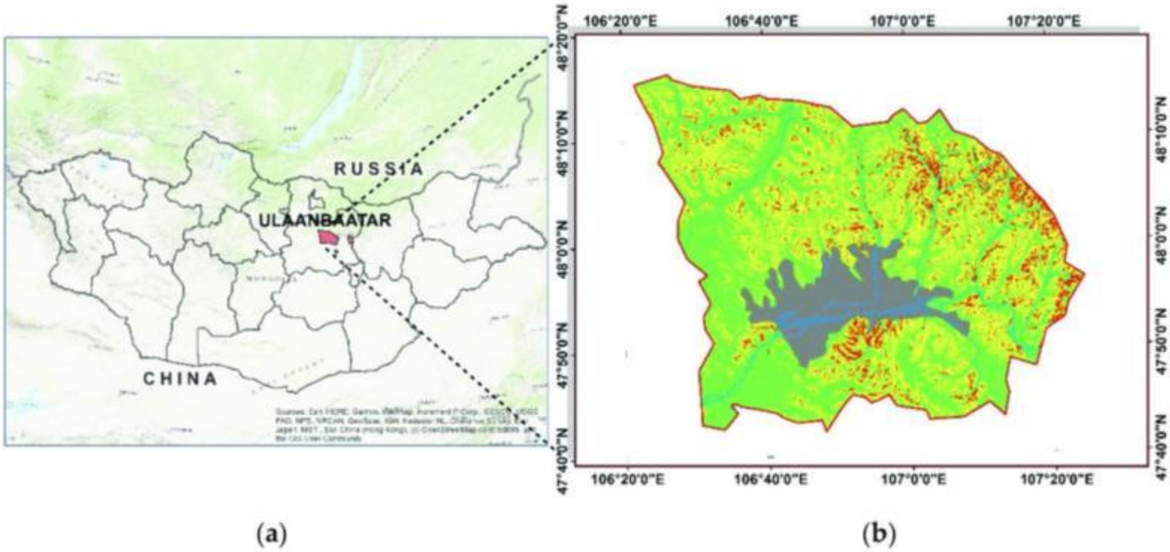

Fig 2. Map of study area. (a) Location of Ulaanbaatar (b) area suitable for settlement[1]

The city is located in a discontinuous permafrost zone. There is a dense coniferous forest surface and discontinuous permafrost in the north of the city; powdery, carbonized dark soil covers the northern mountains, and swampy soils with permafrost are also common along the Tuer River Valley. The main soil type in the Bogd Khan Mountains is coniferous forest soil. Permafrost in meadow forests is widespread in the higher parts of the mountains. Sedimentary rocks exposed on the edge of the peaks are evenly distributed along the mountain range.

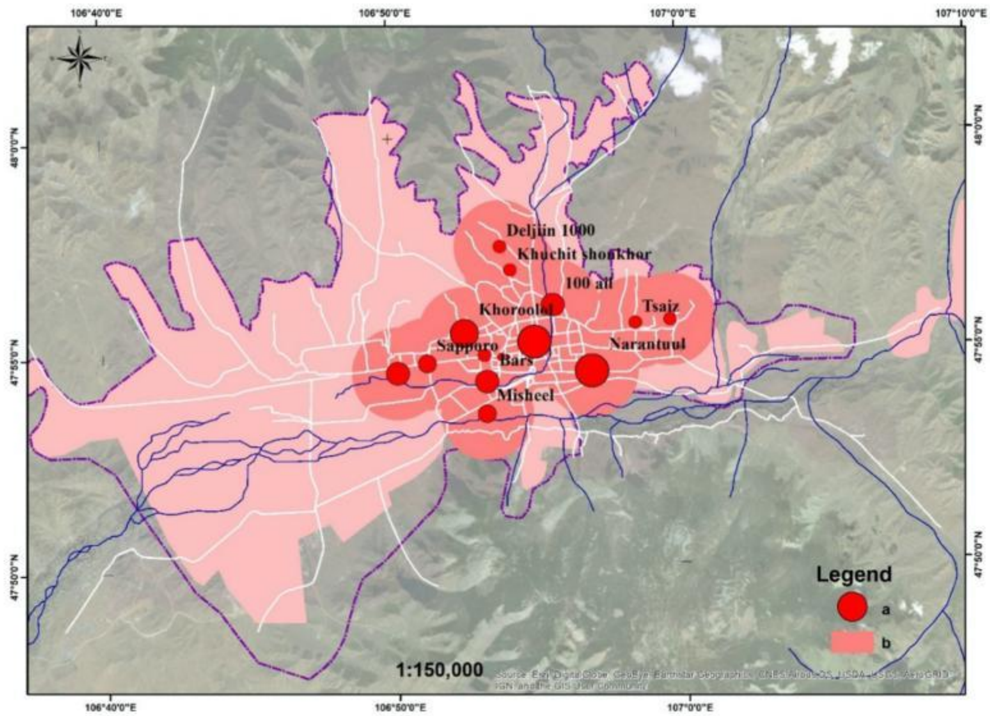

Fig 3. Map of study area. (a) Population concentration points, (b) area suitable for settlement[2]

[1] https://www.amicusmongolia.com/ulaanbaatar-quick-facts.html

[2] https://www.amicusmongolia.com/ulaanbaatar-quick-facts.html

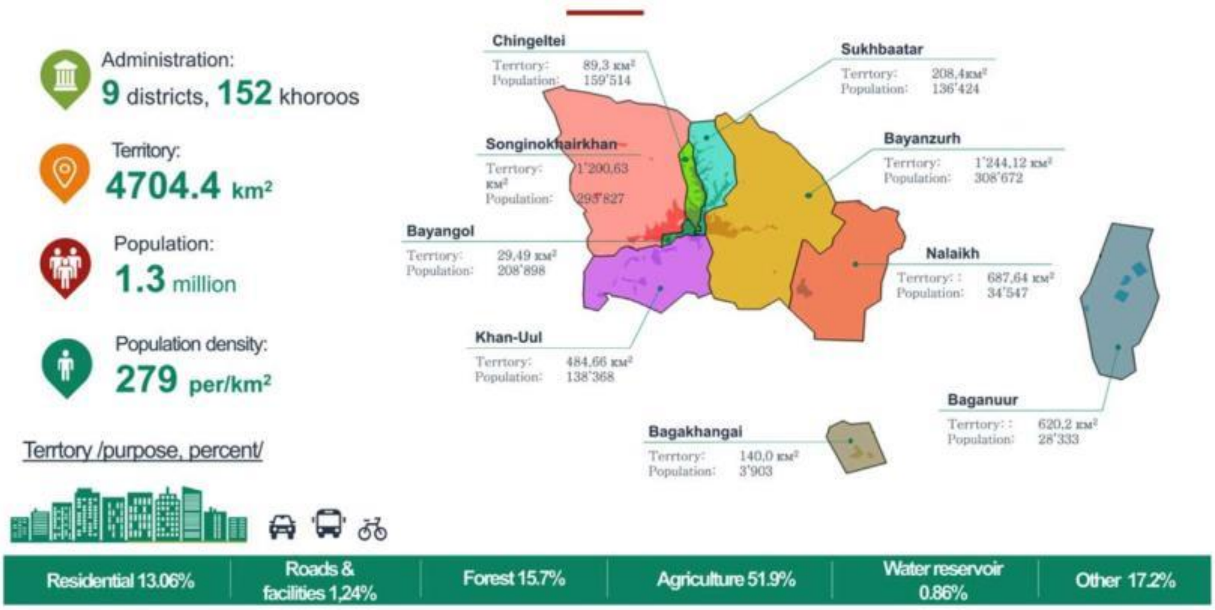

Fig 4. Infographic of Ulaanbaatar city by districts

3. PROPOSED METHODOLOGY

This section outlines the steps involved in the hybrid SWARA-TOPSIS method used to select the best location for a logistics center near Ulaanbaatar, Mongolia. The SWARA method is used to determine the weights of the criteria selected by the expert teams, the TOPSIS method is used to determine the ranking of suppliers in each category. SWARA is a method in which an expert will use his or her own implicit knowledge, information and experiences.

Figure 5 shows the details of the proposed model. We redesigned following model inspired by proposed model in [16]. First, in phase I, we identify the decision maker and obtain his opinion to define the criteria to be used in the location selection of logistics center based on the literature. Then, in phase II, we apply the steps of SWARA to determine the criteria weights and finally, in phase III, we apply TOPSIS to select best location.

3.1 Phase 1: Criteria Selection

A set of criteria that are deemed important for the selection of a logistics center location will be identified. The criteria used in this study were derived through adopting a two-pronged strategy that included literature review and expert consultations. Literature review helped in identifying the most widely used criteria to select logistics centers with reference to best international practice. At the same time, interviews with seven experts in logistics and transport in Mongolia helped to make the criteria relevant and specific to the local context. All five of the selected criteria—access to transportation, labor availability, infrastructure quality, land cost, and proximity to market—were confirmed to be significant in the Mongolian example, particularly for Ulaanbaatar and its surroundings.
All these criteria are significant major factors that define the effectiveness, feasibility, and sustainability of development for logistics hubs.

Based on the literature review and expert opinion, the following criteria were selected:

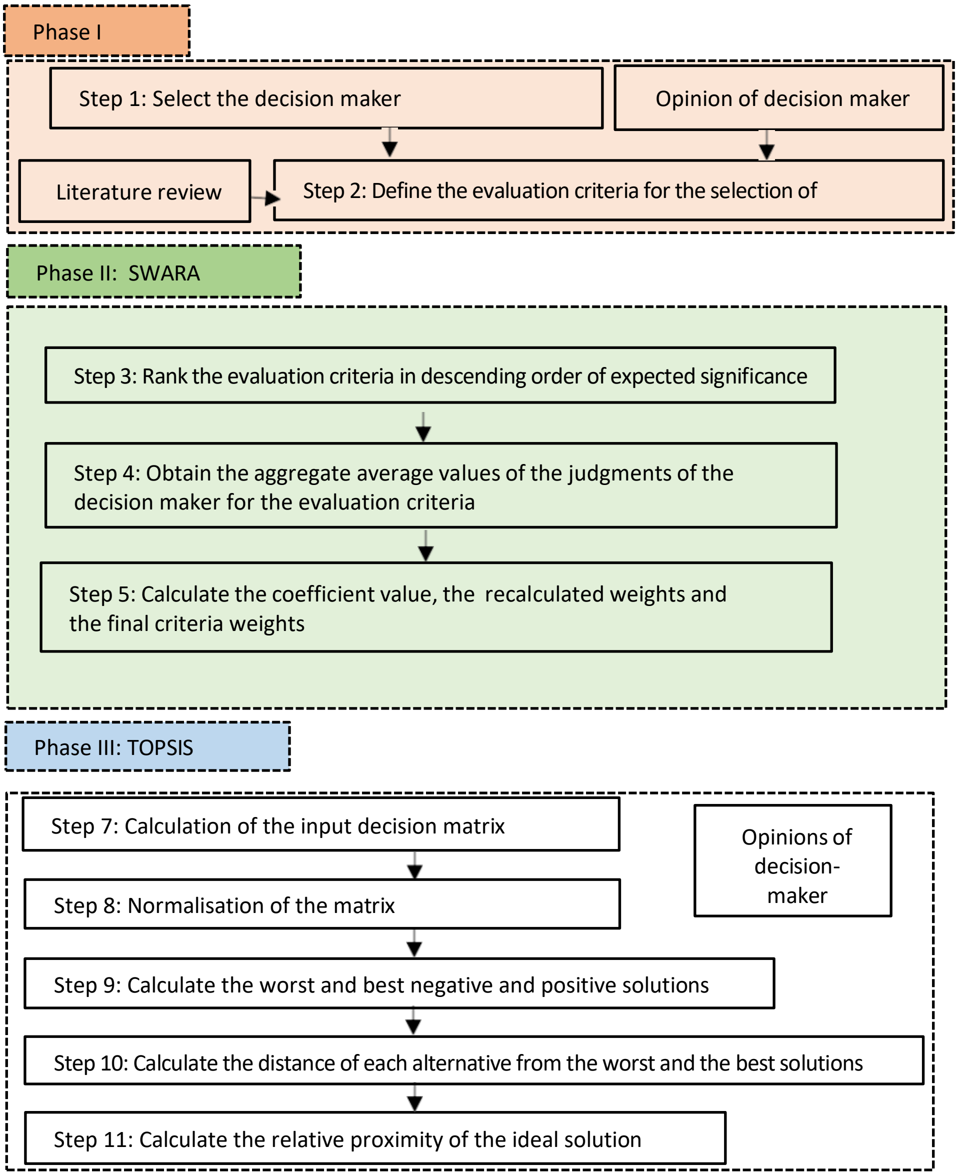

Figure 5. SWARA-TOPSIS Algorithm

Table 1. Criteria definitions

№	Criteria	Abb	Definition
1	Transportation Accessibility	(TC)	The proximity to major highways, railroads, and transportation hubs is critical for a logistics center's performance.
2	Labor Availability	(LA)	Availability of skilled and semi-skilled labor.
3	Infrastructure Quality	(IQ)	Availability of necessary infrastructure such as power, water, communications, and waste management systems.
4	Cost of Land	(CL)	The cost of land acquisition and development.
5	Proximity to Market	(PM)	The distance to key market areas, particularly Ulaanbaatar, which is the economic center of the country.

In this study, 5 most important criteria were used to determine the most suitable areas in terms of logistics centers in Ulaanbaatar. These criteria used in the study were determined in accordance 7 experts' opinions; these are the most common criteria for choosing a logistics center location. The definitions of criteria used in this study are shown in Table 1.

The expert panel had seven experts selected on the basis of their established experience and relevance to the transport and logistics sector. They represented senior academics with doctoral qualifications in transport engineering, logistics experts with a minimum of 10 years of experience in the sector, and policy consultants linked to the Ministry of Road and Transport Development of Mongolia. This cross-disciplinary writing ensured that the perspective remained even-handed in terms of academy, practice, and policy contributions. All the experts had experience in urban planning of transport or construction of logistics networks in Mongolia, and this added more context-specific application and validity to the standards used in the SWARA process.
Each of the criteria measures a significant influence that determines the sustainability, viability, and effectiveness of logistics centre development. This fusion methodology renders the study more transparent and scholarly because it grounds the criteria on experience as well as theory.

3.2 Phase 2: SWARA

The SWARA (Step-wise Weight Assessment Ratio Analysis) method is one of the methods for determining weight values that play an important role in a decision-making process. The method was developed by Kersuliene et al. (2010) [16] and, according to them, its basic characteristic is the possibility of assessing the opinion of experts on the significance of criteria in the process of determining their weights. After defining and creating a list of criteria to be included in the decision-making process, the SWARA method includes the following steps.

Step 1: Step 1: The criteria must be ranked according to importance. In this step, the experts rank the defined criteria according to their importance, e.g., the most important ones are placed first, the least important ones are placed last, and the criteria in between are ranked by importance.

Table 2. Criteria in order of importance and decision matrix

	Criteria	Rank	Sj
1	Accessibility (AC)	1	0
2	Labor Availability (LA)	2	2
3	Infrastructure Quality (IQ)	3	4
4	Cost of Land (CL)	4	4
5	Proximity to Market (PM)	5	5

Step 2: Determine s_j - comparative importance of average value. Starting from the second ranked criteria, it is necessary to determine their significance in the following way. It is determined how much the criteria c_j is more important than the criteria c_{j+1}.

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

Step 3: Calculate the coefficient k_j as follows:

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

Step 4: Determine the recalculated weight q_j as follows:

$$q_j = \begin{cases} 1 & j = 1 \\ q_{j-1}/K_j & j > 1 \end{cases} \quad (3)$$

Step 5: Calculate the weight values of criteria with the sum that is equal to one:

$$W_j = \frac{q_j}{\sum_{k=1}^{m} q_j} \quad (4)$$

where w_j represents the relative weight value of criteria.

Table3 below presents all intermediate results obtained applying the SWARA method

Table 3. Weight of criteria by SWARA method

	name	Sj	Kj=Sj+1	Wj=(Wj-1)/Kj	(Qj=Wj/sum(wj
1	Accessibility (AC)	0	1	1	0.706
2	Labor Availability (LA)	2	3	0.333	0.235
3	Infrastructure Quality (IQ)	4	5	0.067	0.047
4	Cost of Land (CL)	4	5	0.013	0.009
5	Proximity to Market (PM)	5	6	0.002	0.002

3.3 Phase 3: TOPSIS

After assigning weights to the criteria using SWARA, the TOPSIS method is applied to rank potential logistics center locations. TOPSIS method assumes that we have m alternatives (options) and n attributes/criteria, and we have the score of each option with respect to each criterion. Let xij be the score of option i with respect to criterion j. We have a matrix X = (xij) m*n matrix. Let J be the set of utility attributes or criteria (more is better). Let J' be the set of negative attributes or criteria (fewer is better).

As mentioned, there are 5 criteria and 5 alternatives that are ranked based on TOPSIS method. Table 4 describes the criteria and table 5 shows decision matrix, relatively.

Table 4. Characteristics of Criteria

	Criteria	type	weight
1	AC	+	0.706
2	LA	+	0.235
3	IQ	+	0.047
4	CL	-	0.009
5	PM	+	0.002

Table 5. Decision Matrix

	AC	LA	IQ	CL	PM
Location 1	4.714	5.857	5.142	4.428	3.857
Location 2	4.571	5.285	5	3.714	4.142
Location 3	6.142	5	3.428	5	5.571
Location 4	7	5.285	5.2859	5	4.571
Location 5	5	4.571	5.428	4.571	4.571

STEP 1: Normalize the decision-matrix.

The following formula can be used to normalize.

$$r_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad i = 1, \dots, m \quad ; j = 1, \dots \ , n \tag{5}$$

Table 6. The normalized matrix

	AC	LA	IQ	CL	PM
Location 1	0.379	0.502	0.468	0.434	0.377
Location 2	0.367	0.453	0.455	0.364	0.405
Location 3	0.494	0.429	0.312	0.49	0.544
Location 4	0.563	0.453	0.481	0.49	0.446
Location 5	0.402	0.392	0.494	0.448	0.446

STEP 2: Calculate the weighted normalized decision matrix.

According to the following formula, the normalized matrix is multiplied by the weight of the criteria.

$$v_{ij}(\mathrm{x}) = w_j r_{ij}(x) \qquad i = 1, \dots, m \quad ; j = 1, \dots \ , n \tag{6}$$

Table 7. The weighted normalized matrix

	AC	LA	IQ	CL	PM
Location 1	0.267	0.118	0.022	0.004	0.001
Location 2	0.259	0.106	0.021	0.003	0.001
Location 3	0.349	0.101	0.015	0.004	0.001
Location 4	0.397	0.106	0.023	0.004	0.001
Location 5	0.284	0.092	0.023	0.004	0.001

STEP 3: Determine the positive ideal and negative ideal solutions.

The aim of the TOPSIS method is to calculate the degree of distance of each alternative from positive and negative ideals. Therefore, in this step, the positive and negative ideal solutions are determined according to the following formulas.

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+)$$
$$A^- = (v_1^-, v_2^-, \dots, v_n^{-+})$$

So that

$$v_j^+ = \{(max\ v_{ij}(x) |\ j \epsilon j_1) \ , (min\ v_{ij}(x) |\ j \epsilon j_2)\} \ \ i = 1, \dots, m$$
$$v_j^- = \{(min\ v_{ij}(x) |\ j \epsilon j_1) \ , (max\ v_{ij}(x) |\ j \epsilon j_2)\} \ \ i = 1, \dots, m \tag{8}$$

where j1 and j2 denote the negative and positive criteria, respectively.

Table 8. The positive and negative ideal values

	Positive ideal	Negative ideal
AC	0.397	0.259
LA	0.118	0.092
IQ	0.023	0.015
CL	0.003	0.004
PM	0.001	0.001

STEP4: distance from the positive and negative ideal solutions

TOPSIS method ranks each alternative based on the relative closeness degree to the positive ideal and distance from the negative ideal. Therefore, in this step, the calculation of the distances between each alternative and the positive and negative ideal solutions is obtained by using the following formulas.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}[v_{ij}(x) - v_j^+(x)]^2} \quad , \quad i = 1, \dots, m \qquad (9)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}[v_{ij}(x) - v_j^-(x)]^2} \quad , \quad i = 1, \dots, m \qquad (10)$$

The distance to the positive and negative ideal solutions are illustrated in Table 9.

Table 9. Distance to positive and negative ideal points

	Distance to positive ideal	Distance to negative ideal
Location 1	0.13	0.028
Location 2	0.138	0.016
Location 3	0.052	0.09
Location 4	0.012	0.139
Location 5	0.116	0.026

STEP 5: Calculate the relative closeness degree of alternatives to the ideal solution

In this step, the relative closeness degree of each alternative to the ideal solution is obtained by the following formula. If the relative closeness degree has value near to 1, it means that the alternative has shorter distance from the positive ideal solution and longer distance from the negative ideal solution.

$$C_i = \frac{d_i^-}{(d_i^+ + d_i^-)} \quad , \quad i = 1, \dots, m \qquad (11)$$

The table 10 and figure 6 shows the relative closeness degree of each alternative to the ideal solution and its ranking.

Table 10. The ci value and ranking

	Ci	rank
Location 1	0.178	4
Location 2	0.103	5
Location 3	0.631	2
Location 4	0.923	1
Location 5	0.181	3

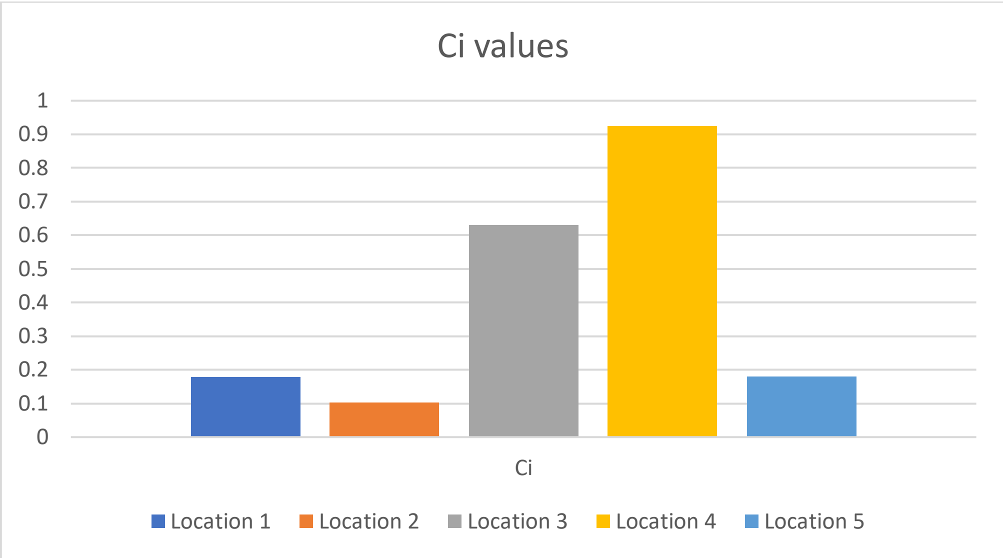

Fig 6. The ci value

3.4 Result and Discussion

We used combination of SWARA and TOPSIS method to select a location for logistics center in Ulaanbaatar. This mixed method easily applied with 5 alternatives of location and 5 most important criteria. Results show the ranking of places based on their performance in selected criteria. Therefore, Location 4 can be given the highest rank due to the transportation accessibility, high quality infrastructure despite the highest land cost.
Further study, we can use a combination of GIS method with this mixed technique in order to visualize the result on map.

№	Alternatives	Location	Coordination
1	Location 1	Batsumber sum, Tuv province – near UB	48.361556, 106.746621
2	Location 2	Amgalan urtuu, Ulaanbaatar	47.902669, 107.016240
3	Location 3	Emeelt area, Ulaanbaatar	47.931649, 106.536622
4	Location 4	Hushig valley, Tuv province-near UB	47.643172, 106.860827
5	Location 5	Baganuur district, Ulaanbaatar	47.773114, 108.374128

Robustness and Sensitivity Issues

To test the sensitivity of the proposed new SWARA-TOPSIS model, future studies are recommended to utilize a framework for sensitivity analysis. It can be carried out by adjusting the weights of certain criteria in a controlled way (e.g., ±10% to ±30%) and verifying the stability of the resulting rankings. For example, changing the weight of the most influential criterion—transportation accessibility—would test how much the final decision depends on this criterion. In addition, the inclusion of a sixth criterion such as environmental sensitivity, the potential ecological footprint of logistics operations at each potential location, would make the decision model more comprehensive. Inclusion of this type of criterion would facilitate harmonization of logistics planning with the country's environmental sustainability goals and enable a check of the robustness of the model's rankings in the presence of new factors. These strategies would enhance the credibility of the model and ensure a more comprehensive validation of its results.

4. CONCLUSION

This paper demonstrates the effectiveness of combining the SWARA and TOPSIS methods for logistics center location selection near Ulaanbaatar, Mongolia. By using a hybrid approach, the study balances subjective expert opinion with objective quantitative analysis. The results indicate that the best location is one that offers a balance between transportation accessibility, infrastructure quality, land cost, and environmental sustainability. The findings provide valuable insights for logistics companies and policymakers in Mongolia, offering a clear decision-making framework that can be applied to similar scenarios in other regions The conclusions of this study have important implications for logistics managers and policymakers in Mongolia. From a managerial perspective, the identification of Hushig Valley as the optimal site for a logistics centre emphasizes the importance of prioritizing infrastructure quality and accessibility over lower land prices. Logistics firms can use this information to guide investment decisions, particularly in weighing the trade-offs of land acquisition. In practice, corporations can explore setting up an alliance with the local government to develop transport corridors and utility infrastructure in top-ranked positions.

For policymakers, the findings give a systematic foundation upon which to base infrastructure planning and regional development policy. The integration of the SWARA-TOPSIS process in public investment decision-making can enhance transparency and ensure development priorities are evidence-driven. In particular, policymakers can use the weighted criteria model to assess the relevance of other logistics-related investments across Mongolia.
For maximizing the use of such decision-support systems, subsequent activities can include additional dynamic features like iterative adjustment of weights for the criteria, inclusion of sustainability indicators, and GIS-based visualization of ranked alternatives.
SWARA-TOPSIS hybrid approach was beneficial in determining a site for a logistics centre in an environment with multiple criteria. The methodology combined the use of expert opinion and objective analysis and provided a clear and replicable decision-making process.
Future work may involve developing GIS tools and other environmental or social sustainability criteria for further improvement in terms of robustness and applicability.

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