Mapping Blood Center Locations In Rajshahi By AHP And TOPSIS

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Abstract

Efficient healthcare system relies on well-placed blood facilities. Blood centers collect donated blood, process it, and deliver it to hospitals for transfusion. Due to the importance of health care, this study addresses blood center placement as a multi-criteria decision-making (MCDM) problem. The purpose of this study is to develop a decision support system for determining the right location within the healthcare system for establishing a blood center in Rajshahi's most densely populated district. The system is developed through MCDM technique, Using the Analytic Hierarchy Process (AHP) combined with TOPSIS, which guides decision-makers in evaluating and selecting appropriate blood center locations. By using the system, identified criterias are weighted by AHP, and then alternatives are ranked by TOPSIS. Based on the normalized criteria weights, the ideal best and worst values of each of Rajshahi's four thanas have been determined. Based on the analysis of all alternatives, a score of six criteria determined Shah Mokhdum a thana to be the top, Motihar thana to be the second, Boalia to be the third, Rajpara thana to be the fourth. Shah Mokhdum thana emerged as the most suitable, since it met all of the criteria. In this strategic process, this integrated approach helps decision-makers make more informed decisions by providing a comprehensive analysis of the alternatives. The proposed blood center will benefit the local community by providing safe blood to those in need.

Keywords
Facility location, AHP, TOPSIS, MCDM.

1. Introduction

Access to reliable and timely blood supply is crucial for effective healthcare delivery. Blood Centers play a vital role in ensuring an adequate and safe blood supply is available for patients in need. However, the selection of blood bank locations requires careful consideration and analysis. With the increasing trends and growing demand for blood, it is essential to carefully plan to ensure an adequate supply of blood. The decision regarding the blood center's placement significantly impacts both the organization's success and the well-being of the population it serves. The uncertainties surrounding the blood supply and demand, perishability of blood, and compatibility of blood types make the selection of blood bank locations a challenging task [2]. In case a blood center is set up in the wrong location, it may lead to inefficiencies, inadequate blood supply, and increased transportation costs. Facility location decisions are particularly important in the healthcare system because any abnormality might lead to mortality or morbidity (Rusman, 2014). It is crucial to employ thorough and efficient decision-making methods for selecting the location of blood banks. During crisis like covid 19 pandemic, natural disasters, or other emergencies, the importance of having easily accessible and strategically placed blood banks becomes even more critical (Larimi, 2022).Rajshahi is one of the most densely populated cities in Bangladesh, and ensuring an efficient blood supply chain is essential to meet the healthcare needs of its residents [5].There is a shortage of safe and reliable blood supply in Rajshahi resulting in difficulty in providing timely blood transfusions to patients. This is caused by various factors such as limited blood bank locations, inadequate infrastructure, and ineffective coordination among blood centers (Chaimae 2020). As a result many people in need of blood are unable to receive the necessary transfusions, leading to adverse health outcomes and potentially avoidable fatalities. To address this issue and improve the blood supply chain in Rajshahi, the use of decision-making models such as the Analytic Hierarchy Process and Technique for Order Preference by Similarity to Ideal Solution is employed to select optimal blood bank locations.

1.1 Objectives

To find the optimal location for a blood bank in Rajshahi City Corporation.

2. Literature Review

Prior research has highlighted the significance of location selection in blood bank management and associated challenges. Various MCDM methods like fuzzy TOPSIS, AHP, and ELECTRE have been used by multiple researchers to address location selection issues across different domains, including healthcare facilities. Fuzzy logic was employed to select the healthcare facility's location using a fuzzy Technique for Order Preference by Similarity to Ideal Solution to pinpoint the best feasible hospital site based on six criteria (Antmen 2019). Additionally, a network optimization model was utilized to analyze blood transportation and allocation with Integer Programming algorithms determining the optimal number, location, and allocation of blood banks while minimizing transportation costs. Two allocation models (single and double) were proposed to meet hospital demand for which ILOG CPLEX software was used for computational experiments (Rusman 2014).Another study focused on blood supply chain operations in emergencies, proposing a four-echelon blood supply chain model (Xiangyu Jin, 2021). Researchers in another study proposed finding temporary blood banks with the shortest possible response time during and after disasters. They employed various methods, such as the Tabu search Heuristic method and Bayesian Belief network, to determine optimal location factors for these facilities. Their findings indicated that response time and ease of access were the most critical considerations in this process (Malhotra 2017).

Another researcher suggested a different approach to creating an efficient supply chain network for blood distribution. They proposed designating specific hospitals as local blood banks and using the rest of the facilities as receivers of blood from these local banks. This would involve more frequent shipments from the local blood banks to reduce inventory levels at each facility. To minimize costs, they developed a mixed integer nonlinear programming model to optimize the selection of blood banks, hospital assignments, and routing decisions for facilities. Additionally, they used a piecewise linear approximation method and employed simulated annealing heuristic approach for problem-solving (Ozkok, 2020).The authors introduced the AHP and PROMETHEE II methodologies to alleviate blood demand in the region by prioritizing collection centers. They compared results from the Analytical Hierarchy Process with those from the Preference Ranking Organization Method for Enrichment Evaluation (N.Arunkumar S.Godwin Barnabas 2012). Researchers focus is on determining the best location in Iran for bioethanol production. They used the best-worst method (BWM) to select the best provenance, which evaluates several decision-making criteria. They proposed a framework based on three dimensions of sustainability: economic, environmental, and social. The weights and performance data identified by BWM are used to calculate an overall score for each province, which is then used to rank the provinces (Siamak Kheybari 2019).

The researcher proposed a prototype framework to help decision-makers choose the best machine among other possible choices. The hierarchical structure of their method includes seven main criteria and twenty-six sub-criteria for selecting the best alternative among the three machines. The AHP method is used to calculate the weights of various criteria, and one of the well-known MCDM methods, TOPSIS, is used to select the most desirable machine (Karmaker, 2016). In another study researchers compared the fuzzy AHP and fuzzy Topsis methods for facility location selection. Five criteria were taken into account: favorable labor climate, proximity to markets, community concerns, quality of life, and proximity to suppliers and resources. Both methods yielded the same results (Karakaşoğlu, 2017).In this study, we used an integrated approach of the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to an Ideal Solution (TOPSIS) method to determine the optimal location of a blood center among four alternative sites. Through expert opinions and literature review, various factors influencing blood bank location are identified. The AHP method was used to determine the weights of the criteria during the assessment procedure, and the TOPSIS method was used to rank the alternative locations.Researchers used TOPSIS, SAW, GRA, and MOORA to select the best plant location. Because their results were contradictory, they used the partial ranking method elimination and choice translating reality (ELECTRE-I) to arrive at the final optimal result. Skilled workers, expansion potential, material availability, investment costs, and site risks were among the criteria used to determine the best solution (Ray, 2015). Researchers proposed VIKOR and Fuzzy VIKOR, evaluation models based on order performance by similarity to the ideal solution, to assist industrial practitioners with performance evaluation in a bivalent and fuzzy environment, where vagueness and subjectivity are handled with linguistic values, respectively. Trapezoidal fuzzy numbers are used to handle uncertain numerical quantities (Mannan, 2014). To better deal with uncertain information and determine the best feasible solution, researchers integrated Entropy and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodologies and applied them in an Interval Valued Pythagorean Fuzzy (IVPF) environment to select the most appropriate site in northern Turkey for establishing a hydrogen energy hydrogen-sulfide (H_2S) decomposition plant **(**Sukran Seker, 2020).Researchers introduced a hybrid AHP-TOPSIS framework to select an optimal site for a fire station in Imam Khomeini port, vital for Iran's economy. Employing a collaborative spatial decision support system, it considers nine criteria, including proximity to hazards and infrastructure, using AHP for criteria weighting and TOPSIS for ranking. The chosen approach yielded a relative closeness value of 0.65, demonstrating its efficacy in site selection during fieldwork **(**Vahidnia **2022)**.

3. Methods

The step wise procedure of AHP is presented as follows:
Step 1: Construct the structural hierarchy.

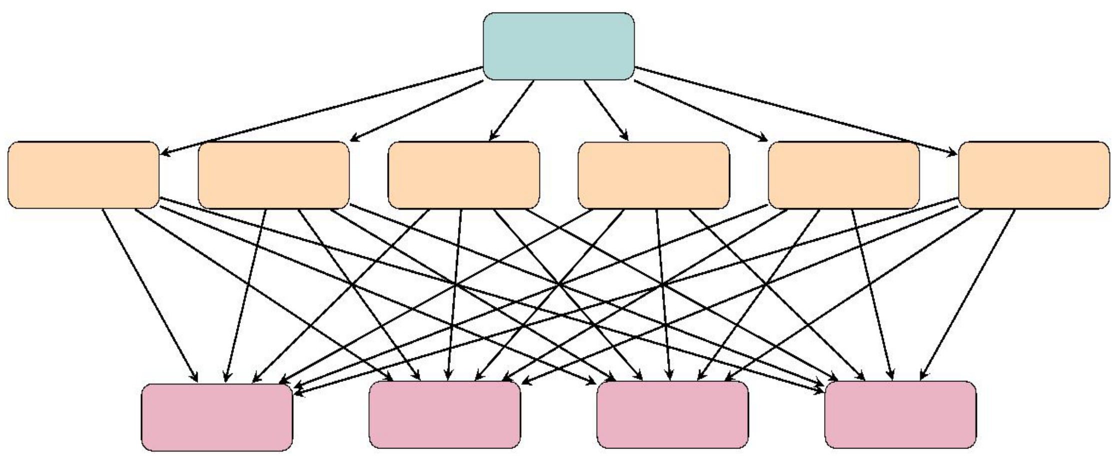

Figure 1. Hierarchical Structure

Step 2: Construct the pairwise comparison matrix.
Assuming n attributes, the pairwise comparison of attribute i with attribute j yields a square matrix A n×n where aij denotes the comparative importance of attribute i with respect to attribute j. In the matrix,

$$a_{ij} = 1 \quad \text{when } i = j, \text{ and } a_{ji} = 1/a_{ij}.$$

$$A_{n\times n} = \begin{matrix} Attribute \\ 1 \\ 2 \\ 3 \\ \vdots \\ n \end{matrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}$$

Step 3: Construct a normalized decision matrix

$$C_{ij}= a_{ij} \Big/ \sum_{J=1}^{n} a_{ij}$$
$$i=1,2,3........n, \quad j=1,2,3.........n$$

Step 4: Construct the weighted normalized decision matrix

$$w_i = \sum_{j=1}^{n} cij/n, \ i=1,2,3.......n,m$$

$$W=\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

Step 5: Calculate Eigenvector & Row matrix

E=N^{th} root value/∑ N^{th} root value

Row matrix $=\sum_{j=1}^{n} a_{ij} \times e_{j1}$

Step 6: Calculate the maximum Eigenvalue, λmax.

λ_{max} = Row matrix/E

Step 7: Calculate the consistency index & consistency ratio.

CI = (λmax−1)/(n − 1), CR = CI/RI

Where n & RI denote the order of the matrix & Randomly Generated Consistency Index respectively (Karmaker, 2016).

3.1 Ranking Alternatives by TOPSIS

Step 1: Construct a normalized decision matrix of beneficial and non-beneficial criteria.

$$r_{ij}=\frac{xij}{\sqrt{\sum_{j=1}^{j} xij2}} \quad J=1,2,3.................,J: \ i=1,2,3......n$$

Where x_{ij} and r_{ij} are the original and the normalized score of the decision matrix respectively.

Step 2: Construct the weighted normalized decision matrix by multiplying the weights w_i of evaluation criteria with the normalized decision matrix $r_{ij.}$

v_{ij} =wi × rij J= 1,2,3,.......j i=1,2,3......n

Step 3: Determined the positive ideal solution (V_{j+}) and negative ideal solution (V_{j-})

A*={v1,v2,v3...........vn}maximum values

Where v_i*= {max(v_{ij}) if j∈J ; min(v_{ij}) j∈J^- }

Step 4: Calculate the separation measures of each alternative from PIS and NIS

S_i^+ $=[\sqrt{\sum(vij-vj)(vij-vj)}]$^0.5]

Step 5: Calculate the relative closeness coefficient to the ideal solution of each alternative

Performance score $= S_i^+ \Big/ S_i^+ + S_i^-$,i=1,2,……,J.

Step 6: Based on the decreasing values of the closeness coefficient, alternatives are ranked from most valuable to worst. The alternative having the highest Performance score (Pi) is selected (Karmaker, 2016).

Criteria for Blood Bank Location Selection:

- Accessibility (A): Easy access for donors and patients via road and public transport (Rusman, 2014).
- Population Density (P): High density for a larger donor pool.
- Hospitals (H): Close to hospitals for efficient blood transportation.
- Existing Blood Banks (B): How many blood banks are in the location.
- Environmental Factors (E): Safe from pollution and hazards (Antmen, 2019).
- Travel Time and Travel Costs (T): Short travel, lower costs (Antmen, 2019).

4. Data Collection

Data were collected from various regions in Rajshahi city through a survey conducted by visiting blood banks and hospitals. The valuable opinions of Doctors and Healthcare specialists were used in the analysis of the critical criteria for selecting a location for a Blood Center facility and identifying potential alternative locations.
There are Four Thanas In Rajshahi City Corporation. These are-
Rajpara Thana
Boalia Thana
Shah Mokhdum Thana
Motihar Thana

Table 1. Pair-wise comparison matrix for AHP

	Accessibility	**Population density**	**Hospitals**	**Blood Bank**	**Environmental factors**	**Travel time and travel costs**
Accessibility	1.000	0.333	0.143	0.333	0.333	0.200
Population density	3.000	1.000	0.200	0.333	0.333	0.250
Hospitals	7.000	5.000	1.000	2.000	4.000	0.333
Blood Bank	3.000	3.000	0.500	1.000	1.000	0.500
Environmental factors	3.000	3.000	0.250	1.000	1.000	0.333
Travel time and travel costs	5.000	4.000	3.000	2.000	3.000	1.000

The pairwise comparison matrix was created using the results of a survey conducted on authorities of blood centers and health care officials. The survey aimed to identify six criteria that were deemed important for evaluating the performance of blood centers. The matrix presents a comparison of these six criteria in pairs.

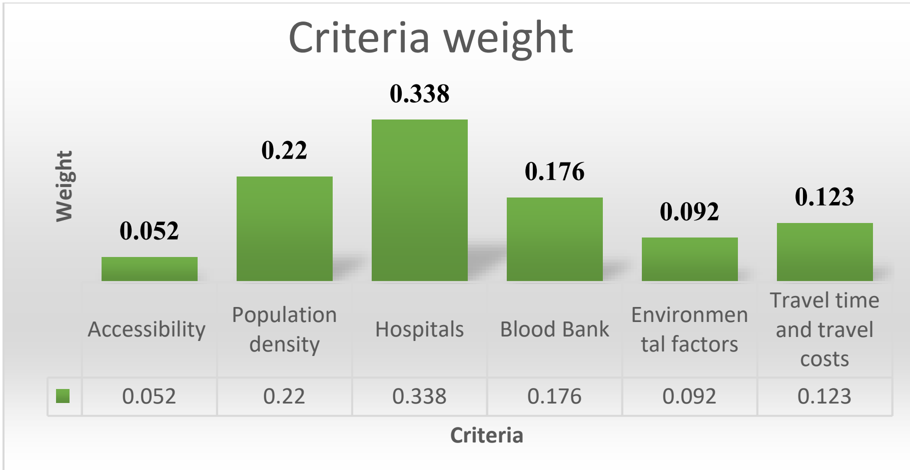

Figure 2. Normalized weights of main criteria

This table presents data on population density and the number of health services in each thana within Rajshahi City Corporation. The data was collected using Google Maps and the 2021 census. In addition, information on environmental factors and travel time was gathered through surveys conducted with blood centers and hospital authorities in the city.

Table 2. Data collection of the alternative and criteria

		Criteria					
		Population density(km2)	Hospitals	Accessibility	Blood Banks	Environmental factor	travel time and cost
Alternative	Rajpara Thana	11941	17	5	6	4	4
	Boalia Thana	11640	5	4	2	3	3
	Shah Mokhdum Thana	3707	1	3	1	3	4
	Motihar Thana	7025	6	3	3	3	3

Table 3**.** Calculation of Ideal Best & Ideal Worst Value

		Criteria					
Alternative		Population density(km2)	Hospitals	Accessibility	Blood Banks	Environmental factor	travel time and travel cost
	Rajpara Thana	0.04491554	0.251313344	0.027643662	0.122019195	0.076237085	0.193640343
	Boalia Thana	0.043783341	0.07391569	0.02211493	0.040673065	0.057177814	0.145230258
	Shah Mokhdum Thana	0.013943715	0.014783138	0.016586197	0.020336532	0.057177814	0.193640343
	Motihar Thana	0.026424225	0.088698827	0.016586197	0.061009597	0.057177814	0.145230258
	V_{j+}	0.04491554	0.251313344	0.027643662	0.020336532	0.076237085	0.145230258
	V_{j-}	0.013943715	0.014783138	0.016586197	0.122019195	0.057177814	0.193640343

Ideal Best & Ideal Worst Value was calculated by step 3.

Table 4. Calculation of performance index

Attribute	Si_{+}	Si_{-}	Si_{+} + Si_{-}	Pi
Rajpara Thana	0.005525821	0.239564847	0.138580971	0.319772134
Boalia Thana	0.065365588	0.115664852	0.135439843	0.608350331
Shah Mokhdum Thana	0.115067189	0.101682662	0.162651153	0.706195732
Motihar Thana	0.092975887	0.108097177	0.154205111	0.611400783

Table 5. Finding rank using Pi value

Attribute	**Pi**	**Rank**
Rajpara Thana	0.319772134	1
Boalia Thana	0.608350331	2
Shah Mokhdum Thana	0.706195732	4
Motihar Thana	0.611400783	3

The rank in Table 5 is calculated using the Pi value. The highest value is given a rank of 1, the second highest value is given a rank of 2, and so on. The lowest value is given the last rank position.

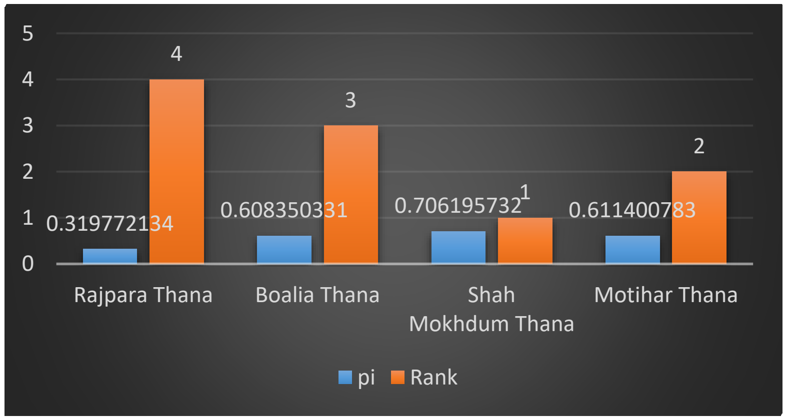

Figure 3. Rank Choice

Consistency check

The maximum Eigenvalue, λ_{max} = Row matrix/E = 6.497693

Consistency index CI=$\frac{\lambda max - n}{n-1}$= 0.099526

RI=1.24

CR= $CI/_{RI}$ = 0.08026 < .10

The Consistency Ratio, CR is less than .10 .so our criteria weights Are consistent.

5. Results and Discussion

In the first phase of our study, we identified and defined a set of critical criteria for evaluating the optimal location of a blood center and conducted pairwise comparisons among these criteria to establish their relative importance. The results of the AHP analysis revealed the hierarchical structure of criteria importance. The weights assigned to each criterion indicated their contributions to the decision-making process. Hospitals emerged as a highly significant factor. Building upon the criteria weights obtained from the AHP analysis, we proceeded to evaluate potential blood center locations using the TOPSIS method. We formulated a decision matrix that integrated data related to each criterion for all possible locations. By calculating the distance of each alternative from the ideal solution and the negative-ideal solution, we quantified the relative closeness of each location to the optimal choice. After evaluating all alternatives, Shah Makhdum Thana emerged as the top performer, Motihar thana is second in rank.

6. Conclusion

In this study, we presented a decision support system that combines AHP and TOPSIS methods to guide the optimal location selection of a blood center in Rajshahi City Corporation. The systematic process of criteria identification, weighting, and alternative ranking offers decision-makers a comprehensive and transparent framework for making strategic choices. Our study contributes not only to the field of healthcare facility location but also to the broader realm of multi-criteria decision-making, offering a practical methodology that can be adapted to various strategic planning scenarios. In the future, researchers can explore the use of other Multi-Criteria Decision Making (MCDM) techniques such as Vikor to solve problems related to blood center facilities. Comparing the results obtained from these different methods can provide further insights. Additionally, the process can be modified by including more criteria, sub-criteria, and alternatives for improved results. Machine learning techniques can be utilized to determine the optimal location for a blood center, by selecting the appropriate algorithm such as supervised or k-means clustering.

Bibliography

Antmen, P. M. , A Healthcare Facility Location Selection Problem with Fuzzy TOPSIS . *European Journal of Science and Technology*(16), 1-2, 2019.

Chaimae, M. a. , Blood collection supply chain management: A critical review and future perspective. *IEEE 6th International Conference on Optimization and Applications (ICOA)* (pp. 1-7), 2020. Beni Mellal, Morocco: IEEE.

Karakaşoğlu, İ. E., , 2016 Comparison of fuzzy AHP and fuzzy TOPSIS methods. *Springer-Verlag London Limited*, 1-13, 2017.

Karmaker, R. K. , Machine Selection by AHP and TOPSIS Methods. *American Journal of Industrial Engineering, 4*(1), 7-13, 2016.

Larimi, N. G. (2022). Integrating GIS in reorganizing blood supply network in a robust-stochastic approach by combating disruption damages. *Socio-Economic Planning Sciences, 82*, 101250, 2022.

Malhotra, B. S. , Dynamic temporary blood facility location-allocation during and post-disaster periods. *Springer Science+Business Media*, 2-10, 2017.

Mannan, P. P. (2014). Use of VIKOR and Fuzzy VIKOR Techniques to Rank the Alternatives (Influencing Factors) of Blood Bank Supply Chain. *International Conference on Science, Engineering and Management Research (ICSEMR 2014)* .

N.Arunkumar S.Godwin Barnabas, N. K. , Facility Layout Selection For The Blood Inventory Using PROMETHEE II Method. *nternational Journal of Engineering Research and Applications, 2*(4), 1-3, 2012.

Ozkok, O. K. , A Blood Bank Network Design Problem with Integrated Facility Location, Inventory and Routing Decisions. *Springer Science+Business Media, LLC, part of Springer Nature, 2020*.

Ray, A. A. , Facility location selection using complete and partial ranking MCDM methods. *International Journal of Industrial and Systems Engineering, 19*(2), 262-276, 2015.

Rusman, A. R. , Blood Banks Location Model for Blood Distribution Planning in Makassar City. *Proceedings of the Asia Pacific Industrial Engineering & Management Systems Conference, 2014.*

Siamak Kheybari, M. K. , Bioethanol facility location selection using best-worst method. *Elsevier pplied Energy 242*, 612-623, 2019.

Sukran Seker, N. A. (2020). Hydrogen production facility location selection for Black Sea using entropy based TOPSIS under IVPF environment. *international journal of hydrogen energy, 45*(32), 15855-15868.

Vahidnia, M. H. (2022). A Spatial Decision Support System Based on a Hybrid AHP and TOPSIS Method for Fire Station Site Selection. *Journal of Geovisualization and Spatial Analysis, 6*(2), 30.

Weber, S. K. (2019). Heuristic approaches for solid transportation-p-facility. *Springer*, 23.

Xiangyu Jin, H. T. (2021). Dynamic Stochastic Optimization of Emergent Blood Collection and Distribution from Supply Chain Perspective. *Complexity*, 15, 2021.

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