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Facility Layout Selection For The Blood Inventory Using PROMETHEE II Method

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Abstract

Blood Inventory Management has attracted significant interest from the Operations Research profession during the last fifteen years. This paper aims to minimize the overall demand for the blood in the region is by prioritizing the collection centre's as per their shortages, wastages, issue delays and outages by comparing the results of analytical hierarchy process (AHP) with PROMETHEE II method

Keywords: Analytic Hierarchy Process, PROMETHEE II.

INTRODUCTION

The location selection decision may be required due to various reasons, like change in production capacity, addition or deletion of product line, change in distribution cost or change in customer demand. Wrong selection of location may result in inadequate qualified work force, unavailability of raw materials, insufficient transportation facility, increased operating expenses or even disastrous effect on the organization due to political and societal interference. Thus, the decision maker must select the location for a facility that will not only perform well, but also it will be flexible enough to accommodate the necessary future changes.

Selection of a proper location involves consideration of multiple feasible alternatives. It is also observed that the selection procedure involves several objectives and it is often necessary to make compromise among the possible conflicting criteria. For these reasons, multi-criteria decision- making (MCDM) is found to be an effective approach to solve the location selection problems. In this paper, the overall demand for the blood in the region is reduced by prioritizing the collection centre's as per their shortages, wastages, issue delays and outages by comparing the results of analytical hierarchy process (AHP) with PROMETHEE II method the preference ranking organization method for enrichment evaluation (PROMETHEE II) is employed to obtain the best choice from a finite set of alternative facility locations. While applying the PROMETHEE II method to solve a real time facility location selection problem [1], it is observed that this method proves its applicability and potentiality to solve such types of decision-making problems with multiple conflicting criteria and alternatives.

PROMETHEE II method is compared with the Analytic Hierarchy Process (AHP) to prioritize the 4 blood collection centers in a zone.

Literature Review

In 1973, Jennings [1] was the first to expand this analysis to a regional level instead of single hospital. Using simulation analysis, he examines a system with a number of identical individual hospital blood banks making decisions based on the same policies. He studies two cases, no blood sharing between hospitals and blood transferring between hospitals, and concludes that when blood is shared, shortages and outdates are reduced. Thus, managing blood on a regional scale with available transfers increases overall efficiency. This simulation also takes into account the distinction between assigned blood and available, unassigned blood. Jennings was the first researcher to understand the true importance of this distinction.

Cohen and Pierskalla [2] in 1975 attempted to use simple equations to set optimal inventory levels. Their analysis uses many variables, such as rates of demand, the return of unused assigned blood back into available inventory, and thus the effects of cross matching. Using simulation, they determine an optimal inventory level based on all significant variables and they also analyze various ordering policies, issuing policies, and cross matching policies while viewing the supply of blood from a regional perspective.This work united many important variables into a single simulation analysis and explored the importance and effect of changing specific values such as the shortage rate.

Randhawa and West [3] proposed a solution approach to facility location selection problems while integrating analytical and multi-criteria decision-making models. Houshyar and White [4] developed a mathematical model and heuristics approach that assigns N machines to N equal-sized locations on a given site such that the total adjacency flow between the machines is maximized. The proposed model is based on a 0-1 integer programming formulation which may produce an optimal, but infeasible solution, followed by the heuristic which begins with the 0-1 integer solution and generates a feasible solution. Owen and Daskin [5] provided an overview of the methodologies that have been developed for solving facility location selection problems.

Chu [6] presented a fuzzy TOPSIS (technique for order preference by similarity to ideal solution) method-based approach for the plant location selection problems. The ratings and weights assigned by the decision makers are first normalized into a comparable scale. The membership function of each normalized rating of each alternative location for each criterion is then developed. A closeness coefficient is proposed to determine the ranking order of the alternatives.
Klose and Drexl [7] reviewed in details the contributions to the current state-of-the-art related to continuous location models, network location models, mixed-integer programming models and their applications to location selection decision. Yong [8] proposed a new fuzzy TOPSIS method which deals with the selection of plant location decision-making problems in linguistic environment, where the ratings of various alternative locations under different criteria and their relative weights are assessed in linguistic terms represented by fuzzy numbers.

Farahani and Asgari [9] presented a TOPSIS methodology to find the supportive centers with the minimum number and maximum quality of locations in military logistic systems.
Onut and Soner [10] employed a fuzzy TOPSIS based methodology to solve the solid waste transshipment site selection problem, where the criteria weights are estimated using analytic hierarchy process (AHP).

Amiri et al. [11] applied TOPSIS method along with heuristics based on fuzzy goal programming to select the best location. The facility location selection problem is solved in three stages, i.e. (a) finding the least number of distribution centers, (b) locating them in the best possible location, and (c) finding the minimum cost of locating the facilities. Although the facility location selection problems have already been solved using different MCDM techniques, this paper makes a maiden attempt to implement another appropriate MCDM approach, i.e. PROMETHEE II method to tackle this complex location selection decision-making problem.

Blood distribution schedules

During the course of a day the Blood Bank receives a random number of transfusion requests for each blood type, each request for a random number of; units. Once a request for a patient is received, the appropriate number of units of that type is removed from free inventory and upon successful cross matching they are placed on reserve inventory for this particular patient. Any of those units that are not transfused are returned back to free inventory. We will define demand to be the number of units requested, and usage to be the number of units transfused. Any units which are not used within their 2l-day lifetime are considered outdated and are discarded from inventory.

The problem of managing blood supplies can be examined at two levels: the individual hospital level, or the regional level. At the hospital level, the objective is to determine decision rules to be used by the Hospital Blood Bank's management for the daily operations of the Blood Bank. Such decisions would involve quantities to collect or order from the Regional Blood Center, units to issue from inventory against transfusion requests, portion of fresh units to be frozen so that their lifetimes are extended, and development of computer information systems to provide accurate and timely information and thus assist with the management of the Blood Bank's inventory management. At the regional level, the objective of a Regional Blood Center is to determine achievable targets of performance within a region, and to set up collection and distribution schedules that will achieve these desirable targets.

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Current Blood Situation

The current trends in supply and demand of blood in the United States present a major problem that needs to be addressed. The growth rate of supply is significantly smaller than the growth in demand. Although total supply of blood (as an aggregate statistic) exceeds total demand in the US, the disparity between growth rates suggests that major shortage situations are imminent. Understanding the reasons for these growth trends should help identify how to address impending shortages. The mismatch of supply and demand as well as the shrinking gap between available supply and demand is a realistic cause for concern in the future.

METHEDOLOGY

The Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured technique for dealing with complex decisions. Rather than prescribing a "correct" decision, the AHP helps the decision makers find the one that best suits their needs and their understanding of the problem. The AHP provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations.

The outages, shortages for the four collection centre’s has been tabulated as follows

Collection centre1 details;

Demand making criteria’s	No of unit/week
Outages	95
Shortages	165
Issued delay	70
Wastages	100

Collection center 2 details;

Demand making criteria’s	No of unit/week
Outages	100
Shortages	175
Issued delay	65
Wastages	165

Collection center 3 details;

Demand making criteria’s	No of unit/week
Outages	90
Shortages	205
Issued delay	85
Wastages	165

Collection center 4 details;

Demand making criteria’s	No of unit/week
Outages	110
Shortages	220
Issued delay	80
Wastages	100

The use of AHP allows defining a three level hierarchical structure: the top level represents the goal of the analysis, the second level is relative to the relevant criteria used, and the third one defines the possible alternatives.

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques.

Steps involved in AHP

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.

Scoring of the equipments

The values of the previous matrix are obtained by the earlier method, now by using the formula we are going to obtain the weightage for the each issue.

$$S = \sum_{j=1}^{m} (r \times w)$$

Whereas, r - rating factor; W - weightage factor;

The different priority levels reflect the hierarchical relationship between the targets in the objective function where they are arranged in order of decreasing priority (P1>P2>Pm).

S.No	Demand making criteria’s	No of unit/week
1	Outages	385
2	Shortages	765
3	Issued delay	300
4	Wastages	525

These are the data’s of the blood demands in the 4 hospitals in a region for 8 types of blood types now in order to find the priority among these criteria’s the pair wise comparison is made against each of the criteria’s from these values the inconsistency ratios are obtained .now the scoring of the of the each of the criteria’s is obtained as follows:

$$S = \sum_{j=1}^{m} (r \times w)$$

Here the rating factor is obtained by the inconsistency ratios (IR) averages of the each of these criteria’s such as outages, shortages, issue

delays, wastages .the weightage factor is obtained by making pair wise comparison is made for each of the criteria's with one another. From the priorities obtained the goal programming is formulated by the decreasing priority order as follows:
P1>P2>P3….>Pm

Results of AHP

Ranking	Demand criteria	Priority	Priority values
1.	Issue delay	P3	0.273
2.	Wastages	P4	0.255
3.	Shortages	P2	0.248
4.	Outages	P1	0.218

The decreasing priority is of the form P3>P4>P2>P1, the priorities obtained from the AHP results are compared with the PROMETHEE II method.

PROMETHEE II method

Preference function based outranking method is a special type of MCDM tool that can provide a ranking ordering of the decision options. The PROMETHEE (preference ranking organization method for enrichment evaluation) method was developed by Brans and Vincke in 1985 [11]. The PROMETHEE I method can provide the partial ordering of the decision alternatives, whereas, PROMETHEE II method can derive the full ranking of the alternatives. In this paper, the PROMETHEE II method is employed to obtain the full ranking of the alternative locations for a given industrial application.

The procedural steps as involved in PROMETHEE II method are enlisted as below [11, 12]:

Step 1: Normalize the decision matrix using the following equation:

$$R_{ij} = \frac{[X_{ij} - \min(X_{ij})]}{[\max(X_{ij}) - \min(X_{ij})]}$$

$$(i = 1,2 \ldots . n, j = 1,2 \ldots . . m)$$

where X_{ij} is the performance measure of ith alternative with respect to jth criterion.

For non-beneficial criteria, Eqn. (1) can be rewritten as follows:

$$R_{ij} = \frac{[\max(X_{ij}) - X_{ij}]}{[\max(X_{ij}) - \min(X_{ij})]}$$

Step 2: Calculate the evaluative differences of i^{th} alternative with respect to other alternatives. This step involves the calculation of differences in criteria values between different alternatives pair-wise.

Step 3: Calculate the preference function, P_j (i,i′).

There are mainly six types of generalized preference functions as proposed by Brans and Mareschal [12, 13]. But these preference functions require the definition of some preferential parameters, such as the preference and indifference thresholds. However, in real time applications, it may be difficult for the decision maker to specify which specific form of preference function is suitable for each criterion and also to determine the parameters involved. To avoid this problem, the following simplified preference function is adopted here:

$$P_{ij}(i, i') = 0 \; if \; R_{ij} \leq R_{i'j}$$

$$P_j(i, i') = (R_{ij} - R_{i'j}) \; if \; R_{ij} > R_{i'j}$$

Step 4: Calculate the aggregated preference function taking into account the criteria weights.

Aggregated preference function,

$$\pi(i, i') = \frac{[\sum_{j=1}^{m} W_j \times P_j(i, i')]}{\sum_{j=1}^{m} W_j}$$

where w_j is the relative importance (weight) of j^{th} criterion.

Step 5: Determine the leaving and entering outranking flows as follows:

Leaving (or positive) flow for i^{th} alternative,

$$\varphi^+(i) = \frac{1}{n-1} \sum_{i'=1}^{n} \pi(i, i') \; (i \neq i')$$

Entering (or negative) flow for i^{th} alternative,

$$\varphi^-(i) = \frac{1}{n-1} \sum_{i'=1}^{n} \pi(i', i) \; (i \neq i')$$

where n is the number of alternatives.

Here, each alternative faces (n–1) number of other alternatives. The leaving flow expresses how much an alternative dominates the other alternatives, while the entering flow denotes how much an alternative is dominated by the other alternatives. Based on these outranking flows, the PROMETHEE I method can provide a partial preorder of the alternatives, whereas, the PROMETHEE II method can give the complete preorder by using a net flow, though it loses much information of preference relations.

Step 6: Calculate the net outranking flow for each alternative.

$$\varphi(i) = \varphi^+(i) - \varphi^-(i)$$

Step 7: Determine the ranking of all the considered alternatives depending on the values of ϕ (i).The higher value of ϕ (i), the better is the alternative. Thus, the best alternative is the one having the highest ϕ (i) value.

The PROMETHEE method is an interactive multi-criteria decision-making approach designed to handle quantitative as well as qualitative criteria with discrete alternatives. In this method, pair-wise comparison of the alternatives is performed to compute a preference function for each criterion. Based on this preference function, a preference index for alternative i over i′ is determined. This preference index is the measure to support the hypothesis that alternative i is preferred to i′. The PROMETHEE method has significant advantages over the other MCDM approaches, e.g. multi-attribute utility theory (MAUT) and AHP. The PROMETHEE method can classify the alternatives which are difficult to be compared because of a trade-off relation of evaluation standards as non comparable alternatives. It is quite different from AHP in that there is no need to perform a pair-wise comparison again when comparative alternatives are added or deleted.

ILLUSTRATIVE EXAMPLE:

Rao [1] employed the graph theory and matrix approach (GTMA) for selection of the best facility location for a given industrial application. The same example is considered here to demonstrate the applicability and effectiveness of PROMETHEE II method as a MCDM tool. This example takes into account eight facility location selection criteria and three alternative facility locations. The objective and subjective information regarding different location selection criteria are given in Table 1. All these criteria, except the cost of labor, are expressed subjectively in linguistic terms. The objective values for these criteria are assigned from an 11-point scale, as given in Table 2. The fuzzy judgments average (A), above average (AA), high (H) and very high (VH), shown in Table 1, are considered equivalent to good, very good etc. with respect to different criteria. The 4 selection criteria as considered here to affect the location selection decision are closeness to emergency areas (CM), closeness to other blood bank (CR), low transportation cost (LT), maximum patient coverage (MC).

Table 1 Information for facility location alternatives [1]

Location	**O**	**S**	**I**	**W**
P1	H	VH	H	AA
P2	VH	H	H	VH
P3	A	HHHH	VH	AA
P4	H	VH	A	H

as shown in Table1, are converted to crisp scores using the 11-point scale, as given in Table 2. The transformed objective data, as given in Table 3, are then normalized using Eqn. (1) or (2) and are given in Table 4. Rao [1] determined the criteria weights for the considered criteria as wO = 0.194, wS = 0.387, wI = 0.1518, wW = 0.265, using AHP method and the same criteria weights are used here for PROMETHEE II method-based analysis. Where wO, wS, wI, wW are the weightages for outages, shortages, issue delay, and wastages.

Table 2 11-Point Fuzzy Scale

Linguistic term	**Crisp score**
Exceptionally low	0.045
Extremely low	0.135
Very low	0.255
Low	0.335
Below average	0.410
Average	0.500
Above average	0.590
High	0.665
Very high	0.745
Extremely high	0.865
Exceptionally high	0.955

Table 3 Normalized decision matrix

Location	**CM**	**CR**	**LT**	**MCC**
P1	0.6735	1	0	0
P2	1	0	0	1
P3	0	0	1	0
P4	0.6735	1	0	0

Now, the preference functions are calculated for all the pairs of alternatives, using Eqns. (3) and (4), and are given in Table 5. Table 6 exhibits the aggregated preference function values for all the paired alternatives, as calculated using Eqn. (5). The leaving and the entering flows for different location alternatives are now computed using Eqns. (6) and (7) respectively, and are shown in Table 7.

Table 4 Preference functions for all the pairs of alternatives

Location pair	**CM**	**CR**	**LT**	**MC**
(P1,P2)	0	1	0	0
(P1,P3)	0.6735	1	0	0
(P1,P4)	0	0	0	0
(P2,P1)	0.3265	0	0	1
(P2,P3)	1.	0	0	1
(P2,P4)	.3	0	0	1
(P3,P1)	0	0	1	0
(P3,P2)	0	0	1	0
(P3,P4)	0	0	1	0

(P4,P1)	0	0	0	0
(P4,P2)	0	1	0	0
(P4,P3)	0.6	1	0	0

Table 5 Aggregated preference function

Location	**P1**	**P2**	**P3**	**P4**
P1	-	0.387	0.518	0
P2	0.329	-	0.46	0.329
P3	0.1521	0.15211	-	0..1521
	0	0.387	0,.518	-

Table 6 Leaving and entering flows for different locations

Location	**Leaving flow**	**Entering flow**
P1	0.30166	0.160
P2	0.372	0.308
P3	0.152	0.498
P4	0.301	0.160

Table 7 Net outranking flow values for different location alternatives

Location	**Net outranking flow**	**Rank**
P1	0.1413	2
P2	0.063	3
P3	-0.346	4
P4	0.143	1

The priorities of the collection centers are as follows P4>P1>P2>P3,

The net outranking flow values for different alternative locations and their relative rankings are given in Table 8. Now, the alternative locations are arranged in descending order according to their net outranking flow values. The best choice of location for the given blood inventory is location 2, which exactly matches with the observations derived. While solving this problem using graph theory and matrix approach. This proves the applicability and potentiality of the PROMETHEE II method for solving complex decision-making problems in prioritizing the collection centre.

Conclusion:

The comparison of AHP- PROMETHEE II in the blood inventory has paved the way to minimize the demand for the blood requirement in the hospitals in a particular region by prioritizing shortages, outages, issue delay, and wastages in the 4 collection centers. The above said methodology is to minimize the overall deviations for blood demand region or location by prioritizing the collection centers as per their shortages, outages, issue delay, and wastages in the collection centers. In future the optimal blood inventory can be developed by using the dynamic programming model, markov chain and regression model etc.

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