Desirability Function Approach for Selection of Facility Location: A Case Study

Prasad Karande
Department of Mechanical Engineering,
Veermata Jijabai Technological Institute,
Mumbai, India
pmkarande@me.vjti.ac.in

Prasenjit Chatterjee
Department of Mechanical Engineering,
MCKV Institute of Engineering,
Howrah, India
prasenjit2007@gmail.com

Abstract

The decision of facility location selection for a manufacturing organization affects for a long term on business profitability. This decision is based on many conflicting factors of tangible and intangible nature. Location decision once taken is very difficult to be reversed for the organizations. Therefore, facility location selection is predominant strategic decision domain for the manufacturing organizations. Such complex decisions can be made by application of multi-criteria decision-making (MCDM) methods. Various MCDM methods have previously been used to solve such problems. In this paper, a real time case study is presented for selection of the most suitable plant location site for a private sugar production unit using desirability function approach. This approach is based on a concept of determining global attractiveness of an alternative in the form of overall desirability. The estimated response models for different decision criteria are converted into individual desirability functions using exponential transformation process, that are further aggregated into a composite function. The results derived by using desirability function approach are then confirmed by application of utility concept method, which exactly corroborate with each other. Additionally, single dimensional weight sensitivity analysis proves robustness of the results generated using this approach.

Keywords: Facility Location selection, Utility Concept, Desirability Approach

1. Introduction

The present day global business environment enforces the manufacturing organizations to make accurate decisions on various managerial activities. Facility location selection is one of the most important strategic decisions, as it is concerned with very high investments, and cannot be reverted easily, once executed. Also, the facility location decision entails a long term commitment, and has a great impact on productivity, operating costs and profits of the organizations. The chosen location maintains a major influence on competitive performance of the manufacturing organizations for decades. Requirement for fulfillment of additional contemporary constraints, induced due to introduction of new production systems, like just-in-time manufacturing, supply chain management and lean manufacturing, has further boosted the significance of facility location selection decisions. Therefore, to make the manufacturing organizations perform in the most beneficial way over a long term period, facility location selection decisions need to be treated very accurately.

Facility location selection is the determination of a geographical site on which to locate an organization's operations (facilities), such as factories/plants, retail outlets, warehouses, distribution centers and storage yards. Organizations need such decisions to locate, relocate or expand their operations. Such types of geographical decisions are usually dealt by location theory, which addresses questions of what economic activities are located where and why. According to location theory, organizations choose such locations that maximize their profits, while individuals choose locations that maximize their utility. The best facility location is that which results in higher economic benefits through increased productivity, possesses good distribution network, fulfills requirements of modern production systems and is flexible enough to accommodate necessary future changes. A poor selection of facility location may result in inadequate transportation facility, shortage of raw materials, lack of qualified workforce and disappointed existing workforce, poor customer service, decreased competitiveness resulting loss of competitive advantage, increased operating expenses or even disastrous effect on the organization due to political, social and cultural interferences. On the other hand, a good choice of facility location may cause less transportation cost, maximum usage of resources, better logistic performance, good availability of efficient workforce and better operational efficiencies resulting in higher employee morale and better competitive advantage.

2. Literature Review

The concept of desirability function was first introduced by Harrington in 1965, which was later modified by Derringer and Suich. Karande et al. have demonstrated usefulness of utility concept and desirability function approach for selection of materials for varios applications. In order to select a suitable facility location from the available alternative locations for a given application, the past researchers have applied different mathematical approaches. Canbolat et al. applied multi-attribute utility theory (MAUT) approach for selection of location for an automobile part manufacturing organization looking for a global site for its manufacturing operations. Chou et al. employed fuzzy simple additive weighting method for solving facility location selection problems. The proposed approach integrated fuzzy set theory, factor rating system and simple additive weighting method to evaluate the facility location alternatives. Ertuğrul developed an MCDM approach based on fuzzy technique for order preference by similarity to ideal solution (TOPSIS) method for ranking and selection of an appropriate facility location. Athawale et al. proposed an application of preference ranking organization method for enrichment evaluation (PROMETHEE) II method for evaluation and selection of the best facility location for an industrial application. Choudhary and Shankar proposed a combined fuzzy analytic hierarchy process (FAHP)-TOPSIS-based decision framework for evaluation and selection of the optimal location for a thermal power plant, where fuzzy AHP was applied to calculate criteria weights and TOPSIS method was employed to obtain plant location ranking. Mousavi et al. adopted a novel integrated approach for solving facility location selection problems based on Delphi, AHP and PROMETHEE methods. In that approach, decision criteria were selected with the help of Delphi technique, AHP method was applied for obtaining weights of the chosen criteria and ranking of the feasible alternative facility locations was derived using PROMETHEE method. Chauhan and Singh proved an application of a hybrid method of interpretive structural modelling, fuzzy AHP, and fuzzy TOPSIS methods for the selection of a sustainable location of healthcare waste disposal facility. Kannan et al. demonstrated combined application of TOPSIS and AHP methods for choosing probable location for a manufacturing facility. Jacyna-Gołda and Izdebski introduced a concept of an application of genetic algorithm in choosing the efficient location of warehouses in the logistic network. Tavana et al. have presented a three-stage fuzzy evaluation framework to identify the most convenient location for constructing solar power farms. In the proposed approach, adaptive neuro-fuzzy inference system (ANFIS) was used to derive a coherent set of approximations per each potential discrete location and evaluation criterion. Then, the fuzzy AHP approach was adopted to determine the criteria weights and finally, output of fuzzy inference system (FIS) was accepted to determine the most convenient location for constructing a solar power farm. Sennaroglu and Celebi used combined PROMETHEE and (*Vlsekriterijumska Optimizacija I Kompromisno Resenje)* VIKOR methods for selection of military airport location selection problem, while AHP method was adopted to calculate criteria weights. From the above survey as presented above, it has been observed that in most of the facility location selection papers, the past researchers have mainly emphasized on the application of various MCDM techniques like AHP, TOPSIS, VIKOR and PROMETHEE. However, in the case of many criteria and alternatives, it may turn into intricacy for the decision makers to obtain a clear view of the problem and to evaluate the results due to the involvement of different preferential parameters like preference functions, veto threshold, pair-wise comparison which may be very difficult to define in real time scenarios. In this paper, a modest effort has thus been used to slender this research gap while exploring the suitability of desirability function approach for identifying the best facility location in a real time manufacturing environment.

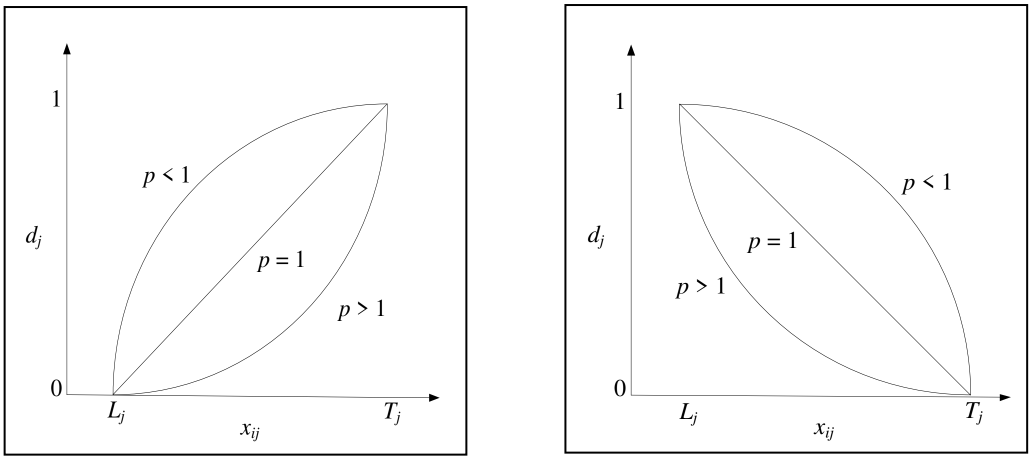
3. Desirability Function Approach

The desirability function approach is based on a concept of determining global attractiveness of an alternative in the form of overall desirability, where the desirability can be defined as a quality of being worthy. In desirability function approach, the estimated response models for different decision criteria are converted into individual desirability functions using exponential transformation process, that are further aggregated into a composite function. If the combined criterion is a simple arithmetic average, it is called as utility function and if it is a geometric mean, it is referred to as Derringer's desirability function. Therefore, utility functions and desirability functions are the decision-making methods based on analogous fundamentals. The desirability function approach is one of the most widely used methods in industry for optimization of multiple response processes. In MCDM problems, each alternative has several properties (criteria), which can easily be converted into overall desirability value. The goal of the DMs is to identify that alternative which can meet the requirements most appropriately. It is anticipated that the most suitable alternative can easily be identified by observing the computed overall desirability values for different alternatives. An alternative with higher overall desirability value implies better suitability for a particular application. The method for computation of overall desirability value is discussed as below.

Let x_{ij} is a performance measure of i^{th} alternative with respect to j^{th} criteria for a decision matrix having m alternatives with n criteria (quality characteristics). For each criterion, the desirability function assigns a dimensionless number d_{ij}. Therefore, it is possible to combine results obtained for each criterion measured on different scales. The scale of desirability function varies from 0 to 1. When $d_{ij} = 0$, the desirability with respect to that criterion is totally unacceptable and when $d_{ij} = 1$, it is completely desirable with respect to that criterion or has an ideal value. The conversion of criteria values into desirability function is done using one-sided or two-sided transformation. One-sided transformation is used when all the criteria are of either beneficial or non-beneficial type. In case of one-sided transformation, the desirability function can be formulated as below:

$$d_{ij} = \begin{cases} 0 & \text{if } x_{ij} \le L_j \\ \left(\dfrac{x_{ij} - L_j}{T_j - L_j} \right)^p & \text{if } L_j < x_{ij} < T_j \\ 1 & \text{if } x_{ij} \ge T_j \end{cases} \tag{1}$$

where L_j is the lower specification limit, selected just below the minimum value for beneficial criteria and just above the maximum value for non-beneficial criteria. T_j is a target value, and takes a maximum value for beneficial criteria and minimum value for non-beneficial criteria, unless other specific target value is defined. The choice of a constant p that governs the shape of the desirability function is usually specified by the DM based on technical, economical and other considerations. For $p = 1$, the desirability function increases linearly towards T_j; for $p < 1$, the function is convex; and for $p > 1$, the function is concave, as shown in Figures 1(a) and (b).



(a) (b)

Figure 1 Desirability function for one-sided transformation (a) maximization and (b) minimization

The desirability function for two-sided transformation can be expressed as follows:

$$d_{ij} = \begin{cases} 0 & \text{if } x_{ij} < L_j \\ \left(\dfrac{x_{ij} - L_j}{T_j - L_j}\right)^s & \text{if } L_j \le x_{ij} \le T_j \\ \left(\dfrac{x_{ij} - U_j}{T_j - U_j}\right)^t & \text{if } T_j \le x_{ij} \le U_j \\ 0 & \text{if } x_{ij} > U_j \end{cases} \tag{2}$$

where U_j is the upper specification limit, and s and t are the two constants that govern the shape of the desirability function. For $s = t = 1$, the desirability function increases linearly towards T_j; for $s < 1$ and $t < 1$, the function is convex; and for $s > 1$ and $t > 1$, the function is concave, as represented in Figure 2.

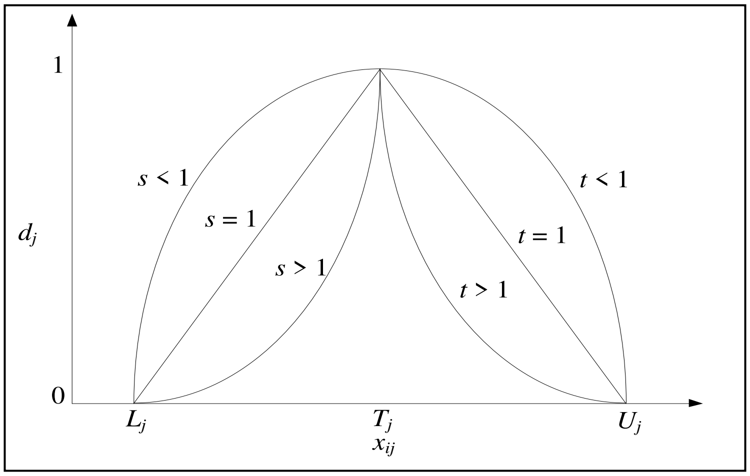


Figure 2 Desirability function for two-sided transformation

For beneficial criteria, the desirability function can be reformulated as follows:

$$d_{ij} = \begin{cases} 0 & \text{if } x_{ij} < L_j \\ \left(\dfrac{x_{ij} - L_j}{T_j - L_j}\right)^s & \text{if } L_j \le x_{ij} \le T_j \\ 1 & \text{if } x_{ij} \ge T_j \end{cases} \tag{3}$$

In case of non-beneficial criteria, the desirability function can be rewritten as below:

$$d_{ij} = \begin{cases} 1 & \text{if } x_{ij} < T_j \\ \left(\dfrac{x_{ij} - U_j}{T_j - U_j}\right)^s & \text{if } T_j \le x_{ij} \le U_j \\ 0 & \text{if } x_{ij} \ge U_j \end{cases} \tag{4}$$

Now, the overall (global) desirability (D) for i^{th} alternative can be calculated employing the following equation:

$$D_i = \left(\prod_{j=1}^{n} d_j\right)^{1/n} \tag{5}$$

The above equation can be remodeled when the weights corresponding to different criteria are taken into consideration as follows:

$$D_i = \left(\prod_{j=1}^{n} d_j^{w_j}\right)^{1/n} \tag{6}$$

This single value of D gives the overall assessment of the desirability of an alternative with respect to all the considered criteria. Clearly, the range of D would fall in the interval (0,1) and D would increase as the balance of the performances becomes more favorable. It can be seen that the value of D increases as the desirability of the corresponding criterion increases. *D* has the property that if any $d_{ij} = 0$ (i.e. if one of the quality characteristics is unacceptable), then $D = 0$ (i.e. the overall product is unacceptable). It is for this reason that the geometric mean, rather than some other function of d_j's, such as the arithmetic mean, is used here. The distinction of Derringer's desirability function from utility function is that if one of the criteria has an unacceptable value, then the alternative possessing such a performance will also be unacceptable. In general, all the decision-making problems involve ranking and selection of the best from several alternatives, and each alternative is assessed for desirability on a number of scored criteria. The alternative with the highest *D* value will be the best choice for any decision-making problem. A high *D* value signifies fulfillment of almost all the requirements for a given alternative with respect to the considered quality characteristics.

4. Example

In this problem, a real time case study is presented for selection of the most suitable plant location site for a private sugar production unit. It is aimed in proposing the best location for the plant in the western region of India. The problem is to compare and evaluate a set of feasible alternative locations with respect to different criteria, which measure the favorable consequences of the alternative plant locations and suggest the best plant location. The objectives of this task are thus finalized as follows:

a) to identify and choose the feasible locations for the sugar plant,
b) to shortlist various evaluation criteria affecting the sugar plant location selection decision,
c) to decide the nature of the considered criteria (qualitative or quantitative) and collect the most accurate information for the quantitative criteria from various sources,
d) to determine the performance of alternative locations with respect to qualitative criteria from a team of DMs, and
e) to rank the candidate plant locations and select the best one.

Table 1 Preference scores with respect to qualitative criteria by DMs

Criteria	Location	DM_1	DM_2	DM_3	Average
AI	PL_1	VH	VH	H	VH
	PL_2	H	H	H	H
	PL_3	H	VH	H	H
	PL_4	AA	H	BA	AA
	PL_5	A	AA	AA	AA
AL	PL_1	VL	L	L	L
	PL_2	H	VH	Ext. H	VH
	PL_3	A	A	AA	A
	PL_4	VH	H	H	H
	PL_5	VH	VH	VH	VH
PRM	PL_1	A	AA	AA	AA
	PL_2	VH	VH	Ext. H	VH
	PL_3	VH	VH	Ext. H	VH
	PL_4	BA	A	H	A
	PL_5	BA	A	A	A
TC	PL_1	VH	H	H	H
	PL_2	L	VL	L	L
	PL_3	L	VL	L	L
	PL_4	BA	A	A	A
	PL_5	VH	VH	H	VH
SCA	PL_1	A	BA	AA	A
	PL_2	L	L	L	L
	PL_3	BA	L	BA	BA
	PL_4	A	A	H	A
	PL_5	BA	BA	A	BA

The considered organization is in the preliminary planning phase of plant installation and operates from a small office under the leadership of a chief promoter supported by a small professional team of chief executive officer (CEO), chief engineer (CE), administrative officer (AO) and supporting staffs. The organization has a plan to construct a sugar plant of 3500 tons of crushing capacity per day (TCD) along with a 15 MW capacity co-generation plant spread over 60 acres of land. The basic responsibility of the team is to plan and execute preliminary strategic decisions, like finalizing the plant location, designing the plant layout, contracting for civil work, procurement and installation of equipment and machineries, staffing, and government liaisoning.

At first, five tentative locations are chosen by the CEO of the organization, based on the outcome of a feasibility study conducted with due consideration of the capabilities of the locations to fulfill the set minimum requirements of the proposed sugar plant. The shortlisted locations are identified as PL_1, PL_2, PL_3, PL_4 and PL_5. A team of DMs consisting of CEO (DM_1), CE (DM_2) and AO (DM_3) is then formed for further decision-making regarding the plant location selection. The outcome of few joint meetings among the DMs results into finalization of six evaluation criteria, i.e. availability of infrastructure (AI), availability of labor (AL), proximity to raw material (PRM), land cost (LC), transportation cost (TC), and social and cultural atmosphere (SCA). Criterion 'AI' considers availability of energy, water and transportation network, criterion 'AL' takes into account availability of skilled labor, unskilled labor as well as managerial and technical staffs, while criterion 'SCA' deals with the cultural issues, quality of life, political environment as well as safety and security. Criteria 'AI', 'AL', 'PRM' and 'SCA' are beneficial, whereas, criteria 'LC' and 'TC' are non-beneficial in nature. The performance measures of all criteria, except 'LC' are expressed in qualitative terms. For quantitative criterion 'CL', the present market price in lakhs of rupees/acre of land is considered for the comparison purpose. However, the 11-point scale is adopted here to express the performance of the qualitative criteria. The DMs rate the qualitative performance of the alternative locations independently, which are converted into corresponding performance sores by taking their average. Furthermore, for systematic conversion of qualitative measures into corresponding fuzzy numerical scores, a numerical approximation approach is also employed.

Table 1 shows the linguistic preference scores set by the DMs to describe the performance of the alternative plant locations with respect to five qualitative criteria. The averages of these preference scores are also provided in Table 1, which are considered as the performance measures for the alternative facility locations with respect to qualitative criteria. The decision matrix for this problem is now developed in Table 2. This decision matrix is then modified while transforming the qualitative performance values into corresponding fuzzy numerical scores in Table 3. Finally, the criteria weights, as given in Table 4, are estimated using entropy method and are subsequently approved by the DMs.

Table 2 Decision matrix

Location	AI	AL	PRM	LC	TC	SCA
PL_1	VH	L	AA	8.50	H	A
PL_2	H	VH	VH	5	L	L
PL_3	H	A	VH	7	L	BA
PL_4	AA	H	A	6.25	A	A
PL_5	AA	VH	A	4.50	VH	BA

Table 3 Modified decision matrix

Location	AI	AL	PRM	LC	TC	SCA
PL_1	0.745	0.335	0.59	8.50	0.665	0.500
PL_2	0.665	0.745	0.745	5	0.335	0.335
PL_3	0.665	0.500	0.745	7	0.335	0.410
PL_4	0.590	0.665	0.500	6.25	0.500	0.500
PL_5	0.590	0.745	0.500	4.50	0.745	0.410

Table 4 Criteria weights

Criteria	AI	AL	PRM	LC	TC	SCA
Weight	0.2414	0.1155	0.2484	0.1208	0.1502	0.1238

In this method, the corresponding L_j and T_j values for the six criteria are first identified in Table 5. For beneficial criteria (AI, AL, PRM and SCA), the L_i values are chosen at 10% below the minimum criteria values and for non-beneficial criteria (LC and TC), they are chosen at 10% above the maximum criteria values. However, for beneficial criteria, the maximum criteria values are set as T_j values and for non-beneficial criteria, the relative minimum criteria values are chosen. Now, the desirability values are evaluated for each performance measure, as given in Table 6.

Table 5 L_j and T_j values

Criteria	AI	AL	PRM	LC	TC	SCA
L_j	0.531	0.3015	0.450	9.35	0.8195	0.3015
T_j	0.745	0.7450	0.745	4.50	0.3350	0.5000

Table 6 Desirability values

Location	AI	AL	PRM	LC	TC	SCA
PL_1	1	0.0755	0.4746	0.1753	0.3189	1
PL_2	0.6262	1	1	0.8969	1	0.1688
PL_3	0.6262	0.4476	1	0.4845	1	0.5466
PL_4	0.2757	0.8196	0.1695	0.6392	0.6594	1
PL_5	0.2757	1	0.1695	1	0.1538	0.5466

Table 7 Weighted and overall desirability values

Location	AI	AL	PRM	LC	TC	SCA	P	D
PL_1	1	0.7421	0.831	0.8103	0.8423	1	0.4209	0.8657
PL_2	0.8932	1	1	0.9869	1	0.8023	0.7072	0.9439
PL_3	0.8932	0.9114	1	0.9162	1	0.9279	0.6920	0.9405
PL_4	0.7327	0.9773	0.6435	0.9474	0.9394	1	0.4101	0.8619
PL_5	0.7327	1	0.6435	1	0.7549	0.9279	0.3303	0.8314

The weighted desirability values and overall desirability scores for the alternative plant locations are given in Table 7. Based on the overall desirability scores, the ranking of the alternative locations is obtained as PL_2-PL_3-PL_1-PL_4-PL_5. Hence, PL_2 is found as the best location for the proposed sugar plant employing the desirability function approach. In order to confirm validity of the results obtained using desirability function approach, the same problem is also attempted by utility concept method. It is derived that the ranking preferences of the alternative facility locations achieved by solving the same problem using utility concept method exactly corroborate with the results of desirability function approach.

6. Sensitivity Analysis

The scores obtained by application of desirability function approach are observed to be an opaque function of the criteria weights. The impact of variation in criteria weights on the output of desirability function approach can be analyzed by performing weight sensitivity analysis.

Table 8 Changing criteria weights for single dimensional weight sensitivity analysis

Set	AI	AL	PRM	LC	TC	SCA
1	0.2911	0.1651	0	0.1705	0.1999	0.1735
2	0.2711	0.1451	0.1	0.1505	0.1799	0.1535
3	0.2511	0.1251	0.2	0.1305	0.1599	0.1335
4	0.2311	0.1051	0.3	0.1105	0.1399	0.1135
5	0.2111	0.0851	0.4	0.0905	0.1199	0.0935
6	0.1911	0.0651	0.5	0.0705	0.0999	0.0735
7	0.1711	0.0451	0.6	0.0505	0.0799	0.0535
8	0.1511	0.0251	0.7	0.0305	0.0599	0.0335
9	0.1311	0.0051	0.8	0.0105	0.0399	0.0135
10	0.1259	0	0.8257	0.0053	0.0347	0.0083

The criteria weights obtained using entropy method are static, however, they depend upon the performances of alternatives with respect to the decision criteria. In this problem, since the performances with respect to five out of six decision criteria are chosen by DMs, it includes subjectivity and biasness with the DMs perceptions. Therefore, a weight sensitivity analysis is performed to study the effects of changes in criteria weights on the final rankings of the alternatives. Sensitivity analysis on weights shows the stability of the derived solutions with respect to changes in the criteria weights. In this research work, non-proportional weight sensitivity analysis is performed to investigate the effects of varied criteria weights on the final rankings of the alternatives.

For this non-proportional additive single dimensional weight sensitivity analysis, the most important criterion is first identified as 'PRM' because of its highest priority weight, and the sensitivity analysis is then carried out while varying the weight of this criterion within a range of $0 \leq w_{\text{PRM}} \leq 0.8257$. Beyond the upper limit of w_{PRM}, the weight of criterion 'AL' becomes negative. Therefore, the weight of criterion 'PRM' is varied between 0 and 0.8257 in steps of 0.1, as shown in Table 8. While increasing or decreasing the weight of 'PRM' criterion, the same amount is equally apportioned among the weights of other criteria maintaining the weight additivity constraint.

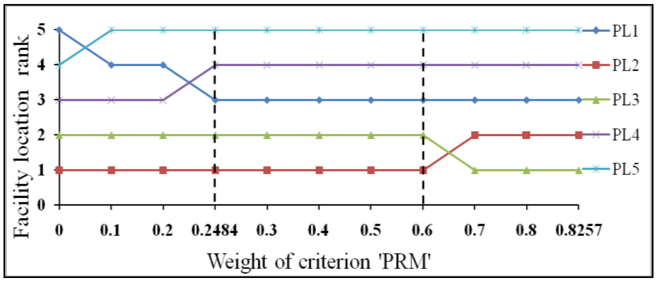


Figure 3 Weight sensitivity analysis

Now, after computing the new sets of criteria weights, the ranking performances of the alternative facility locations are reevaluated, as displayed in Figures 3. From this figure, it is observed that the ranking of alternative PL_2 is maintained over a range of $0 \leq w_{\text{PRM}} \leq 0.6$, but when $w_{\text{PRM}} \geq 0.6$, location PL_3 becomes the top rank. The ranking performances of the other alternative facility locations also do not show much variation during weight variation. The obtained results for the facility location selection problem are therefore definite.

7. Conclusions

This paper presents a desirability function-based approach for facility location selection problem from a set of candidate alternatives in manufacturing environment. This method is based on the quality characteristic values of the considered location alternatives for arriving at the satisfactory results. The basic concept of desirability function is to convert a multi-objective problem into a single objective function with the consideration of overall desirability. This concept uses individual desirability and overall desirability. The higher value of overall desirability indicates the best alternative. One real time facility location selection example is considered to demonstrate the application competence and suitability of the proposed method. The result obtained using the desirability function-based method almost substantiate with those derived by utility theory method which signify that this method is an efficient approach as compared to other well established facility location selection methods like AHP, VIKOR, PROMETHEE, TOPSIS, ELECTRE etc in which most of these techniques either require very lengthy computations involving pair-wise comparisons or they need some preferential parameters to be defined which may be very complicated for the decision makers in practical situations. Also, a non-proportional weight sensitivity analysis is performed to examine the robustness of the proposed method.

References:

1) Harrington, E.C.Jr., The desirability function, Industrial Quality Control, 21(10), 494-498, 1965.
2) Derringer, G. and Suich, R., Simultaneous optimization of several response variables, Journal of Quality Technology, 12(4), 214-219, 1980.
3) Karande, P., Gauri, S. and Chakraborty, S. Applications of utility concept and desirability function for materials selection, Materials and Design, 45, 349-358, 2013.

4) Canbolat, Y., Chelst, K. and Garg, N., Combining decision tree and MAUT for selecting a country for a global manufacturing facility, Omega, 35(3), 312-325, 2007.
5) Chou, S-Y., Chang, Y-H. and Shen, C-Y., A fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes, European Journal of Operational Research, 189(1), 132-145, 2008.
6) Ertuğrul, İ., Fuzzy group decision making for the selection of facility location, Group Decision and Negotiation, 20(6), 725-740, 2011.
7) Athawale, V., Chatterjee, P. and Chakraborty, S., Decision making for facility location selection using PROMETHEE II method, International Journal of Industrial and Systems Engineering, 11(1-2), 16-20, 2012.
8) Choudhary, D. and Shankar, R., An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India, Energy, 42(1), 510-521, 2012.
9) Mousavi, S., Tavakkoli-Moghaddam, R., Heydar, M. and Ebrahimnejad, S., Multi-criteria decision-making for plant location selection: An integrated Delphi-AHP-PROMETHEE methodology, Arabian Journal for Science and Engineering, 38(5), 1255-1268, 2013.
10) Chauhan, A. and Singh, A., A hybrid multi-criteria decision making method approach for selecting a sustainable location of healthcare waste disposal facility, Journal of Cleaner Production, 139, 1001-1010, 2016.
11) Kannan, G., Garg, K., Gupta, S. and Jha, P., Effect of product recovery and sustainability enhancing indicators on the location selection of manufacturing facility, Ecological Indicators, 67, 517-532, 2016.
12) Jacyna-Gołda, I. and Izdebski, M., The multi-criteria decision support in choosing the efficient location of warehouses in the logistic network, Procedia Engineering, 187, 635- 640, 2017.
13) Tavana, M, Arteaga, F. J. S., Mohammadi, S. and Alimohammadi, M., A fuzzy multi-criteria spatial decision support system for solar farm location planning, Energy Strategy Reviews, 18, 93-105, 2017.
14) Sennaroglu, B. and Celebi, G., A military airport location selection by AHP integrated PROMETHEE and VIKOR methods, Transportation Research, Part D, 59, 160-173, 2018.

Biographies

Dr. Prasad Karande is an Associate Professor in Department of Mechanical Engineering at the Veermata Jijabai Technological Institute, Mumbai, India. He earned B.E. in Mechanical Engineering from Shivaji University, India, Masters in Production Engineering with specialization in Manufacturing from Mumbai University, India and PhD in Engineering from Jadavpur University, Kolkata, India. He has published many research papers in leading journal and conferences. Dr. Karande has taught under graduate and post-graduate courses in industrial engineering, operations research, supply chain management etc. His research interests include multi-criteria decision-making, supplier selection, optimization and manufacturing.

Dr. Prasenjit Chatterjee received his post-graduation and Doctoral degrees in Engineering from Jadavpur University, Kolkata, India and is currently working as an Associate Professor of Mechanical Engineering Department at MCKV Institute of Engineering, India. He has published more than 51 research papers in leading international journals of repute and peer reviewed conferences. His research focus is in the areas of Operations Research, multi-criteria decision-making, multi-objective decision-making, advanced manufacturing technologies, sustainable materials selection and green supply chain management. He has been actively involved in teaching under graduate and post graduate courses, research and administrative activities. He has conducted several guest lectures by eminent academicians and industry professionals. He is in Editorial Board, organizing committee and programme committee of several international journals and peer reviewed conferences.