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INTEGRATED MULTI CRITERIA DECISION MAKING FOR MANUFACTURING PLANT LOCATION SELECTION

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Abstract

Selection of the manufacturing facility location is an important decision criteria for any new organization desirous of setting up a new plant or shifting of an existing plant. This decision primarily affects the capital investment in the new project and long term growth of the business from the market share perspectives. Therefore selection of the plant location plays an important role in the long run success of business. For plant location selection decision several criteria viz. availability of cheap land and raw materials, sufficient electricity and water, transportation, closeness to market, availability of skilled and unskilled manpower, government policies and tax regimes etc. need to be considered. The viable decision to select the plant location is solely based on number of the multiple criteria or alternatives which justify the application of Multi Criteria Decision Making (MCDM) for efficient and reliable decision making. In this paper, the alternatives are evaluated with an integrated multi criteria decision making methodology, using the three popular methods viz. Delphi, Analytical Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The paper showcase the applicability of these decision making techniques for a new plant location selection for any new or existing firm.

Keywords:-: MCDM, AHP, TOPSIS, Location selection, Delphi, Manufacturing

1. INTRODUCTION

In this competitive world, every company wants to increase their market share, so expansion of the business is necessary. In any business expansion the most important decision of the company is to make sure that guaranteed return will be there on the capital investment. The decision of selecting location for new plant development is very critical because it consists of large amount of investment and it decides the success of the project. For accurate decision, good decision makers need a large amount of relevant data for assessing effectively the alternatives considering different criterions (Ankita Ray, 2015) (Mousavi, -Moghaddam, M. Heydar, & S. Ebrahimnejad, 2012). The process needs to take into consideration various factors such as proximity to market, supply of material, transportation facility, infrastructure availability, labours and wages, etc (Chatzoglou, Chatzoudes, & Petrakopoulou, 2018). The literature shows that impact of the criterions on the decision-making process depends on the type of industry and the scale of expansion.

To solve this complex problem with high precision, some decision-making model is used such as multi criteria decision making (MCDM). As MCDM technique have been applied to solve plant location problem as an excellent and powerful tool particularly throughout the last decade (Abbas Mardania, 2015). There are various methods used in multi-criteria decision making such as Analytical Hierarchy Process, Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) etc. and these methods are having different advantages and have evolved to accommodate various types of application (Mark Velasquez, 2013).

(Mark Velasquez, 2013) (Abbas Mardania, 2015), studied and showed that how the multicriteria decision making techniques have been evolved and how small variation to existing methods causing the development of new fields of research. Several techniques, such as SAW, TOPSIS ,AHP ,Fuzzy AHP are used in plant location selection problem (Ankita Ray, 2015) (Mousavi, -Moghaddam, M. Heydar, & S. Ebrahimnejad, 2012). The decision is completely dependent on the criteria's decided based on which the decision is to be done. There are various factors which varies industry to industry, the factors also vary from medium scale to large scale industry and the impact of different factors is different in every problem (Chatzoglou, Chatzoudes, & Petrakopoulou, 2018).

The MCDM techniques are used to solve various problem such as selection of supplier for the company, based on the company's requirement the factors are decided and the ranking of the suppliers are done (Vipul Jain, 2016). Some studies have done with the help of fuzzy logic to solve the problem of facility location selection, by using the application of fuzzy TOPSIS method (Ferhan Çebia, 2015). These MCDM techniques is used in various industries such as nuclear plant location as this decision involve the highest risk in making the decision and also should be very precise (Melike Erdogan, 2015). So, they have used type-2 fuzzy AHP by giving weights to the criteria's and further used to rank the alternatives. There have also been use of geographic information system and multicriteria decision making for the evaluation of the wind farm site selection in Greece. Also, these techniques are used in ranking a suitable desalination plant, here they have considered sustainability aspect also to rank the desalination plant location criteria in United Arab Emirates (UAE) by taking into consideration social, environmental, economic and many other aspects (Fikri Dweiria, 2018). The application of MCDM is also done in the field of project management (Jabbarzadeha, 2017), selection of the contractors for awarding the sub projects is very important for any project to be successful. The study shows the use of six criteria's such as experience, manpower resource, quality performance, for evaluating different contractors. Here TOPSIS method was used to rank the alternative contractors according to the criteria.

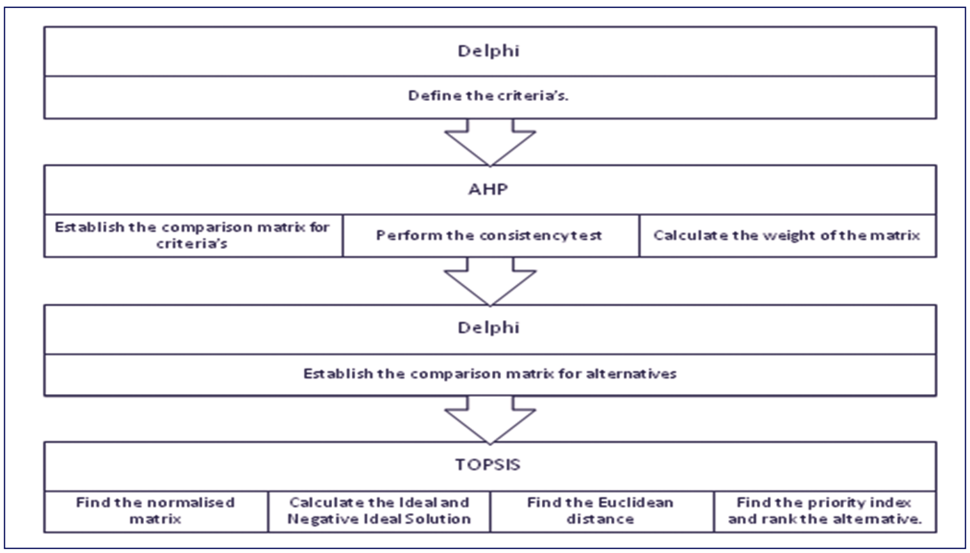
MCDM is also applied in construction field for selection of the site (Z. Turskis, 2015), they have used a hybrid model in which weighted aggregated sum product assessment method with fuzzy is used. The have selected a site for shopping centre in Vilnius in which several qualitative and quantitative attributes exist for ambiguities and vagueness. Also, there is case of Istanbul for the selection of the landfill site. This study shows that three landfill sites were evaluated through expert opinion and by facilitating fuzzy AHP and Fuzzy TOPSIS. Few studies show's that this MCDM techniques is also used in wind solar complementary power generation (Wenjun Chen, 2017). Here they have used an analytic network process for the calculation of the weights, and they have used a cloud model in combination with preference ranking organization method.

In 2017, the site selection for a power plant was done using Analytical Hierarchy Process, for which data have been collected for the sites with the capacity factor of 25% or above for 600KW wind turbine and applied MDCM to find the most suitable to least suitable site for the installation of wind farm with respect to different factors (Yousaf Ali, 2017). A photovoltaic solar plant location was selected in 2017 using a hybrid MCDM which comprises of interpretive structural modelling, fuzzy ANP and VIKOR (Amy H. I. Lee, 2017).

2. PROPOSED METHODOLOGY

The proposed methodology is specifically designed to make the use of MCDM more effective for plant selection problem. The three different techniques used in this work viz. Delphi, Analytical Hierarchy Process (AHP) and technique for order of preference by similarity to an ideal solution (TOPSIS) are integrated in order to rank the alternative. Here Delphi technique is used to select the best criteria among the set of possible problems considering all aspects of problem under consideration. Also, to provide alternatives values with respective to each criteria and form the assessment matrix. Further the weights for each criteria are calculated by applying AHP after formulation of the decision hierarchy and finally the TOPSIS method is used to rank the alternatives.

Fig.1. Proposed Integrated methodology for plant location selection



2.1. Delphi Method

This technique is a group technique used for decision making with the help of the group of experts or decision makers that communicates in written. The group of experts share their skills, expertise, knowledge and judgements till we get a mutual consensus (Chandra Sekhara, 2015). This technique has the following steps.

i. Selection of the decision maker.

ii. Conduct the first round of survey. it consists of some basic open-ended questions, which show the response of the expert in that particular domain and the investigator can form a structured questionnaire.

iii. Then conduct the second round of survey, here the question is asked based on the data collected in first round. Here the priorities and importance of each criteria are defined by the experts, so as a result of second round areas of disagreement and agreement are identified.

iv. In third round each decision maker will be provided with a questionnaire have standard scale of rating.

v. And further assimilate a group of decision makers opinion and to reach a consensus.

vi. Also, repeat the step (iv) and (v) until a consensus is reached.

2.2. Analytical Hierarchy process (AHP) and Technique for order of preference by similarity to an ideal solution (TOPSIS)

This techniques are most widely used for solving decision making problems. It solves a multilevel hierarchy structure of alternatives, criteria's and sub-criteria. the problem is solved using a set of pair wise comparison matrix. These matrices are used for determining the weights importance of the decision criteria. Also, it is used to find out whether the data provided is consistent with the help of the consistency test. The AHP technique as explained by Mousavi et al, (Mousavi, -Moghaddam, M. Heydar, & S. Ebrahimnejad, 2012) is applied in this work. Technique for order of preference by similarity to an ideal solution (TOPSIS) facilitates the decision maker to formulate the problem in a simple manner to carry out analysis and ranking of the alternatives of the real-world problem. The steps which are given by (Chandra Sekhara, 2015) are used for this work.

3. APPLICATION OF A PROPOSED METHODOLOGY FOR A MANUFACTURING COMPANY

3.1. Criteria considered for plant location selection

The proposed integrated methodology has been applied to the company named Fluid Controls Pvt. Ltd., a Pune based manufacturing company which is being relocated to new location. In view of facility expansion in order to increase its production capacity the company is looking for a new location for manufacturing its plant. The decision to move to new location demands big capital investment for a considerable long term. The cost associated with land acquisition, plant construction, transportation etc. is also very high. Therefore, this decision amounts to the highest risk. Any wrong decision will lead to increase in operating cost, insufficient raw material, inefficient worker etc. Hence the decision maker should select the plant location in such a way that the plant will perform well, and it will be flexible for future changes in the company. The criteria such as availability of raw material, transportation facility, labours and wages etc. can be considered while selecting the new plant. Various criteria considered for the plant location decision making problem is shown in the Table 1.

Table.1 List of decision criteria

Sr. No.	Criteria considered here for decision making	
1	Proximity to market	PM
2	Supply of material	SM
3	Transport facility	TF
4	Infrastructure availability	IA
5	Labours and wages	LW
6	Economies of scales	ES
7	Investment Cost	IC
8	Political environment	PE

3.2. Pair wise comparison of Criteria

SaatyT.L. (1990) proposed AHP which enables decision makers to develop a hierarchical structure for the factors which are explicit in the given problem and to provide judgment about the relative importance of each of these factors specify a preference for each decision alternative with respect to each factors, providing a prioritized ranking order of preference for decision alternatives. Intensities of importance, used, for consideration of matrix have been selected on the basis of recommendation given by Saaty, which indicates the definition of individual intensity of importance with necessary explanations.

3.3. Methodology in detailed steps

Step 1: An expert committee of three members having the domain knowledge, experience and expertise has been formed for assessment and to select the most appropriate criteria using Delphi. For implementation of the integrated methodology, three decision makers have been conferred with full authority to collect the data regarding plant relocation feasibility and carry out systematic analysis. These experts from the top management of the company and having minimum experience of 15 years in manufacturing industry have been selected. After detailed study for about six months and due considerations of all the factors involved, committee had come up with four locations viz.Chakan, Bhosari, Ranjangaon and Goa. First three locations are located near to existing plant location and last one is located about 300 km away from existing location in the adjacent state. Assessment of criteria have been carried out by Delphi method as explained in section.3. The criteria are defined as shown in Table. 1 and a nine-pointer scale is applied for assigning weightage to the criteria as shown in Table.2

Table.2 Initial Matrix

Decision Maker1									
Criteria	PM	SM	TF	IA	LW	ES	CP	LA	PE
PM	1.00	0.20	0.14	0.17	0.25	3.00	0.33	7.00	5.00
SM	5.00	1.00	4.00	6.00	4.00	3.00	2.00	5.00	4.00
TF	7.00	0.25	1.00	3.00	5.00	4.00	3.00	8.00	6.00
IA	6.00	0.17	0.33	1.00	4.00	2.00	3.00	9.00	3.00
LW	4.00	0.25	0.20	0.25	1.00	3.00	0.17	5.00	6.00
ES	0.33	0.33	0.25	0.50	0.33	1.00	0.20	6.00	7.00
IC	3.00	0.50	0.33	0.33	6.00	5.00	1.00	7.00	8.00
LA	0.14	0.20	0.13	0.11	0.20	0.17	0.14	1.00	2.00
PE	0.20	0.25	0.17	0.33	0.17	0.14	0.13	0.50	1.00
Decision Maker 2									
Criteria	PM	SM	TF	IA	LW	ES	CP	LA	PE
PM	1.00	0.25	0.13	0.33	0.17	6.00	0.20	5.00	6.00
SM	4.00	1.00	3.00	5.00	7.00	2.00	5.00	3.00	5.00
TF	8.00	0.33	1.00	0.50	6.00	5.00	7.00	9.00	2.00
IA	3.00	0.20	2.00	1.00	7.00	6.00	0.33	7.00	4.00
LW	6.00	0.14	0.17	0.14	1.00	0.50	0.33	9.00	8.00
ES	0.17	0.50	0.20	0.17	2.00	1.00	0.14	5.00	6.00
IC	5.00	0.20	0.14	3.00	3.00	7.00	1.00	5.00	4.00
LA	0.20	0.33	0.11	0.14	0.11	0.20	0.20	1.00	5.00
PE	0.17	0.20	0.50	0.25	0.13	0.17	0.25	0.20	1.00

Decision Maker 3									
Criteria	PM	SM	TF	IA	LW	ES	CP	LA	PE
PM	1.00	0.50	0.14	0.11	0.33	9.00	0.17	8.00	7.00
SM	2.00	1.00	8.00	7.00	2.00	9.00	0.33	9.00	5.00
TF	7.00	0.13	1.00	4.00	3.00	6.00	0.33	5.00	4.00
IA	9.00	0.14	0.25	1.00	6.00	7.00	0.20	7.00	6.00
LW	3.00	0.50	0.33	0.17	1.00	5.00	0.33	4.00	3.00
ES	0.11	0.11	0.17	0.14	0.20	1.00	0.25	6.00	0.33
IC	6.00	3.00	3.00	5.00	3.00	4.00	1.00	9.00	9.00
LA	0.13	0.11	0.20	0.14	0.25	0.17	0.11	1.00	0.17
PE	0.14	0.20	0.25	0.17	0.33	3.00	0.11	6.00	1.00

Step 2: - The decision hierarchy as explained in Fig.1 has been applied here for the plant location selection problem. The pair wise comparison matrix as explained by Saaty. is used here considering all the mentioned criteria in Table 1. The pair wise comparison matrix quantifies the importance of one criteria over others and gives the first hand information about the relative importance of criteria is the basic step in this methodology. Three matrices obtained by pair wise comparison are integrated into a single matrix by arithmetically calculating geometric mean of each decision matrix with respect to corresponding criterion. The Table.3 shows the integrated matrix.

Step 3: - Finally the weights of the criteria is calculated as shown in Table.4. Here the geometric mean of each criteria is divided by the sum of the geometric mean of corresponding row. After the weights are calculated, these weights are used in TOPSIS method for the ranking of the alternatives.

Table.3 Integrated Matrix

Integrated criteria comparison matrix								
Criteria	PM	SM	TF	IA	LW	ES	CP	PE
PM	1	0.3	0.1	0.2	0.2	5.45	0.2	5.9
SM	3.4	1	4.6	5.9	3.8	3.77	1.5	4.6
TF	7.3	0.2	1	1.8	4.5	4.93	1.9	3.6
IA	5.5	0.2	0.6	1	5.5	4.37	0.6	4.2
LW	4.2	0.3	0.2	0.2	1	1.95	0.3	5.2
ES	0.2	0.3	0.2	0.2	0.5	1	0.2	2.4
IC	4.5	0.7	0.5	1.7	3.8	5.19	1	6.6
PE	0.2	0.2	0.3	0.2	0.2	0.41	0.2	1

Table.4 Criteria Weight

Criteria	GM	Weights
PM	0.579612077	0.05322
SM	3.135093232	0.28785
TF	2.143904224	0.19685
IA	1.527726623	0.14027
LW	0.766671427	0.07039
ES	0.389776268	0.03579
IC	2.077931614	0.19079
PE	0.270585902	0.02484

Table.5 Pairwise comparison of alternatives with respect to criteria's

	Proximity to market							Transportation Facility					
	C	B	G	R	GM	Weights		C	B	G	R	GM	Weights
C	1	4	5	3	2.7838	0.504	C	1	3	8	5	3.309	0.599
B	0.25	1	6	0.33	0.841	0.152	B	0.33	1	3	0.25	0.707	0.128
G	0.2	0.167	1	0.143	0.263	0.047	G	0.125	0.33	1	0.5	0.379	0.068
R	0.33	3	7	1	1.626	0.295	R	0.2	4	2	1	1.124	0.203
	5a) Pairwise comparison matrix of alternatives for the proximity to market criteria							5b) Pairwise comparison matrix of alternatives for the transportation facility criteria					
	Supply of material							Infrastructure availability					
	C	B	G	R	GM	Weights		C	B	G	R	GM	Weights
C	1	6	4	2	2.632	0.534	C	1	8	6	5	3.935	0.518
B	0.167	1	2	3	1	0.203	B	0.125	1	4	5	1.257	0.165
G	0.25	0.5	1	0.33	0.452	0.091	G	0.167	0.25	1	2	0.537	0.071
R	0.5	0.333	3	1	0.841	0.171	R	2	3	2	1	1.861	0.245
	5c) Pairwise comparison matrix of alternatives for the Supply of material criteria							5d) Pairwise comparison matrix of alternatives for the Infrastructure availability					

	Economies of scale					
	C	B	G	R	GM	Weights
C	1	4	6	5	3.309	0.596
B	0.25	1	3	2	1.106	0.199
G	0.16	0.33	1	0.25	0.343	0.061
R	0.2	0.5	4	1	0.795	0.143

5e) Pairwise comparison matrix of alternatives for the economies of scale

	Political Environment					
	C	B	G	R	GM	Weights
C	1	0.143	0.5	0.5	0.435	0.078
B	7	1	3	6	3.350	0.603
G	2	0.333	1	3	1.189	0.214
R	2	0.167	0.33	1	0.577	0.103

5f) Pairwise comparison matrix of alternatives for the Political environment

	Investment Cost					
	C	B	G	R	GM	Weights
C	1	6	4	0.333	1.682	0.313
B	0.16	1	7	0.5	0.874	0.162
G	0.25	0.143	1	0.143	0.267	0.049
R	3	2	7	1	2.546	0.474

5g) Pairwise comparison matrix of alternatives for the Investment cost

	Labour and wages					
	C	B	G	R	GM	Weights
C	1	0.5	3	0.5	0.931	0.205
B	2	1	4	0.33	1.277	0.283
G	0.333	0.25	1	0.5	0.451	0.099
R	2	3	2	1	1.861	0.412

5h) Pairwise comparison matrix of alternatives for the Labour and wages

Step 4: - Now the experts are asked to rate the alternative matrix with respect to each criteria with the help of the Delphi method as explained in section.3. This is done using nine-point scale, as shown in Table.2. And an integrated alternative by criteria matrix is formed by calculating the weights of each alternative with respect to criteria and the Alternative X criteria matrix is formed as shown in Table.5

Step 5: - The normalized decision matrix is calculated and is shown in Table.8. And further the weighted normalized matrix is calculated by multiplication of each element of column to its corresponding weights as shown in Table.9

Table.6 Integrated assessment matrix

Weights	0.053218	0.287853	0.196846	0.14027	0.070393	0.035788	0.190788	0.024844
	PM	**SM**	**TF**	**IA**	**LW**	**ES**	**IC**	**PE**
Chakan (C)	0.504806	0.534463	0.599434	0.518444	0.205818	0.595815	0.313258	0.078305
Bhosari (B)	0.152521	0.203052	0.128065	0.165628	0.282624	0.199223	0.162783	0.603491
Goa (G)	0.047647	0.091739	0.068808	0.070771	0.099923	0.061799	0.049781	0.214208
Ranjangoan (R)	0.295027	0.170746	0.203693	0.245157	0.411635	0.143163	0.474178	0.103996

Table.7 Normalized assessment matrix

Weights	0.053218	0.287853	0.196846	0.14027	0.070393	0.035788	0.190788	0.024844
	PM	SM	TF	IA	LW	ES	IC	PE
C	0.83282395	0.885316	0.92281	0.862485	0.374731	0.920459	0.528032	0.119828
B	0.251627639	0.336347	0.197152	0.275539	0.514573	0.307774	0.274389	0.923506
G	0.07860755	0.151962	0.105927	0.117734	0.181929	0.095472	0.083912	0.327797
R	0.486732629	0.282833	0.313579	0.407844	0.749462	0.221169	0.799282	0.159143

Table.8 Weighted normalized assessment matrix

	PM	SM	TF	IA	LW	ES	IC	PE
C	0.044321225	0.254841	0.181651	0.120981	0.026378	0.032941	0.100742	0.002977
B	0.01339112	0.096819	0.038809	0.03865	0.036222	0.011015	0.05235	0.022944
G	0.004183337	0.043743	0.020851	0.016515	0.012807	0.003417	0.016009	0.008144
R	0.025902937	0.081414	0.061727	0.057208	0.052757	0.007915	0.152493	0.003954

Table.9 Ideal and Negative Ideal solution

V+	0.044321225	0.254841	0.181651	0.120981	0.012807	0.032941	0.016009	0.022944
V-	0.004183337	0.043743	0.020851	0.016515	0.052757	0.003417	0.152493	0.002977

Step 6: - Calculate the ideal and negative ideal solution as shown in Table.10. And the Euclidean distance is calculated and it is shown in Table. 10 Finally the relatedly closeness is calculated and the ranking of the alternatives as shown in Table. 11.

Table.10 Euclidean distance

	SI+	SI-
C	0.088105074	0.295278
B	0.235499165	0.120303
G	0.289886239	0.142305
R	0.264718051	0.07238

Table.11 Relative closeness and rank of the alternatives

	SI+	SI-	PI	Rank
C	0.0881050	0.2952	0.7701	1
B	0.2354991	0.1203	0.3381	2
G	0.2898862	0.1423	0.3292	3
R	0.264718	0.0723	0.21471	4

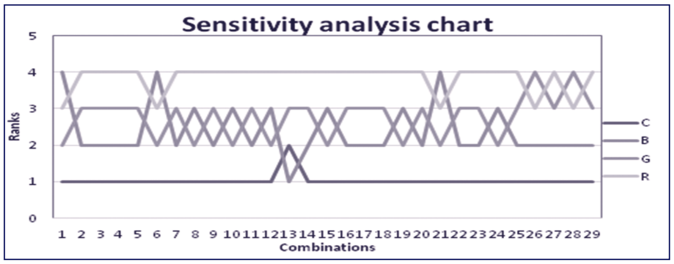
3.4. Sensitivity Analysis

The stability of the priority ranking is done with the help of sensitivity analysis, by assigning the criteria's with equal weights and different weights, i.e. interchanging the weights. Table.12 shows the combinations of different. The sensitivity graph shows that the Chakan location has highest value for all the combinations except thirteenth. Bhosari location has highest value for thirteenth combination. Also, there is much fluctuation in Bhosari and Goa location for third and second rank. Whereas the Ranjangaon location only varying between third and fourth rank. The results of sensitivity analysis illustrate that the ranking of the alternatives changes significantly for different criteria's and it can be observer that the criteria weights play an important role in analysis.

Table.12 Combination of weights of the criteria's

	Criteria								Alternatives			
Combination	PM	SM	TF	IA	LW	ES	IC	PE	C	B	G	R
Main	0.053218	0.287853	0.196846	0.14027	0.070393	0.035788	0.190788	0.024844	1	2	3	4
1	0.287853	0.053218	0.196846	0.14027	0.070393	0.035788	0.190788	0.024844	1	4	2	3
2	0.196846	0.287853	0.053218	0.14027	0.070393	0.035788	0.190788	0.024844	1	2	3	4
3	0.14027	0.287853	0.196846	0.053218	0.070393	0.035788	0.190788	0.024844	1	2	3	4
4	0.070393	0.287853	0.196846	0.14027	0.053218	0.035788	0.190788	0.024844	1	2	3	4
5	0.035788	0.287853	0.196846	0.14027	0.070393	0.053218	0.190788	0.024844	1	2	3	4
6	0.190788	0.287853	0.196846	0.14027	0.070393	0.035788	0.053218	0.024844	1	4	2	3
7	0.024844	0.287853	0.196846	0.14027	0.070393	0.035788	0.190788	0.053218	1	2	3	4
8	0.053218	0.196846	0.287853	0.14027	0.070393	0.035788	0.190788	0.024844	1	3	2	4
9	0.053218	0.14027	0.196846	0.287853	0.070393	0.035788	0.190788	0.024844	1	2	3	4
10	0.053218	0.070393	0.196846	0.14027	0.287853	0.035788	0.190788	0.024844	1	3	2	4
11	0.053218	0.035788	0.196846	0.14027	0.070393	0.287853	0.190788	0.024844	1	2	3	4
12	0.053218	0.190788	0.196846	0.14027	0.070393	0.035788	0.287853	0.024844	1	3	2	4
13	0.053218	0.024844	0.196846	0.14027	0.070393	0.035788	0.190788	0.287853	2	1	3	4
14	0.053218	0.287853	0.14027	0.196846	0.070393	0.035788	0.190788	0.024844	1	2	3	4
15	0.053218	0.287853	0.070393	0.14027	0.196846	0.035788	0.190788	0.024844	1	3	2	4
16	0.053218	0.287853	0.035788	0.14027	0.070393	0.196846	0.190788	0.024844	1	2	3	4
17	0.053218	0.287853	0.190788	0.14027	0.070393	0.035788	0.196846	0.024844	1	2	3	4
18	0.053218	0.287853	0.024844	0.14027	0.070393	0.035788	0.190788	0.196846	1	2	3	4
19	0.053218	0.287853	0.196846	0.070393	0.14027	0.035788	0.190788	0.024844	1	3	2	4
20	0.053218	0.287853	0.196846	0.035788	0.070393	0.14027	0.190788	0.024844	1	2	3	4
21	0.053218	0.287853	0.196846	0.190788	0.070393	0.035788	0.14027	0.024844	1	4	2	3
22	0.053218	0.287853	0.196846	0.024844	0.070393	0.035788	0.190788	0.14027	1	2	3	4
23	0.053218	0.287853	0.196846	0.14027	0.035788	0.070393	0.190788	0.024844	1	2	3	4
24	0.053218	0.287853	0.196846	0.14027	0.190788	0.035788	0.070393	0.024844	1	3	2	4
25	0.053218	0.287853	0.196846	0.14027	0.024844	0.035788	0.190788	0.070393	1	2	3	4
26	0.053218	0.287853	0.196846	0.14027	0.070393	0.190788	0.035788	0.024844	1	2	4	3
27	0.053218	0.287853	0.196846	0.14027	0.070393	0.024844	0.190788	0.035788	1	2	3	4
28	0.053218	0.287853	0.196846	0.14027	0.070393	0.035788	0.024844	0.190788	1	2	4	3
Equal weights	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	1	2	3	4

Fig.3. Sensitivity graph



4. RESULTS AND DISCUSSION

The TOPSIS result indicates that the Chakan location is the best location followed by Bhosari, Goa and Ranjangaon-Pune respectively as shown in Table.12. The consistency of the pairwise comparison matrix is high, and the consistency ratio is less than 0.1. The results of the sensitivity analysis illustrate that the decision of making Chakan location best of all the alternatives is much consistent with different as well as equal weights of the criteria.

5. CONCLUSION

The efficient working of any manufacturing company depends on the location where it is situated. The company should have all the facilities near to the plant whichever is required. The decision maker selects the location based on different multiple criteria.

In this paper the, plant location problem is solved by comparing the location alternatives based on the identified criteria considered by the Delphi method. The experts share their skill and judgment to reach a mutual agreement on the criteria's. Further the AHP and TOPSIS methods have been used in the proposed methodology. This study highlights the importance of the plant location decision selection problem in the context of an integrated Delphi-AHP-TOPSIS method, utilised to determine the manufacturing plant location. Also, there are limited studies on hybrid MCDM methods for researching plant location selection problem. The future work in this field can be to develop a new framework and by adopting computational technique such as neuro-fuzzy, particle swam optimization ant colony optimization, which is the new path for future research.

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