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EVALUATION AND SELECTION OF PROJECTS USING ANALYTIC HIERARCHY PROCESS IN A MANUFACTURING INDUSTRIAL SECTOR

S. Gayathri[1] and Dega Nagaraju[2]
[1]School of Business Management, VIT University, Vellore, Tamil Nadu, India
[2]School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India

ABSTRACT

This paper considers five different projects in the perspective of manufacturing industrial sector. For evaluation and selection of these projects a set of six factors; realism, capability, flexibility, ease of use, cost and ease of computation are considered. Using Analytic Hierarchy Process (AHP), the global weights of five different projects are computed. In the proposed work, first, the pairwise comparison matrix is prepared for all the six set of factors under consideration using Saaty's scale. Then, normalised matrix is prepared to verify the consistency of pairwise comparison matrix and the priority weights are computed. Similarly, with respect to each factor, the pairwise comparison matrix and normalized matrix are prepared for all five projects. Also, the consistency index is verified for all the five projects. Finally, the global weights are computed for all five projects. Based on the findings of this work, it is concluded that the project one is most prioritised and project two is least prioritised.

Keywords: decision making; project selection; manufacturing industry; analytic hierarchy process.

INTRODUCTION

In the current day competitive business world, the process of evaluating an investment project has become an important decision making criteria. Due to globalization and privatization, the investment opportunities in various fields of businesses have become challenging for the investors. Especially, in the present day scenario of ever growing technological advancement, the life cycle of the product has been reducing. Thus, in order to meet the objectives of the parent organization, evaluation and selection of projects has become significant. The principle of project management can be applied to any project and to any industry. However, the relative degree of importance of these principles can vary from project to project and industry to industry. When multiple objectives are important to a decision maker, then, it may be very difficult to choose the project. In such cases, the use of the multi criteria decision making approaches plays a significant role in taking optimal decisions.

Nowadays, most of the organizations have been facing several difficulties regarding the selection and evaluation of projects. These difficulties are due to the complexity of the problems arised before decision making process. From the literature, it is evident that the selection of projects is a complex problem as it involves qualitative and quantitative issues that are frequently conflicting. Both the risk and uncertainty management are necessarily important factors in prioritization of projects (Ghasemzadeh and Archer, 2000). In order to deal with the complexity of decision making process involving multiple criteria, supporting methods like AHP are used. These methods are helpful in assisting and guiding the decision maker to evaluate the alternative projects (Gomes, Gomes and Almeida, 2006).

AHP is a kind of multi criteria decision making (MCDM) technique (Arbel and orgler, 1990). Bagchi's (1989) applied AHP for carrier selection decisions and demonstrated the ease of use. Cheng and Li (2001) used AHP for prioritizing the information to improve resource allocation for the projects. The AHP helped in qualitatively decomposing an unstructured problem into a decision hierarchy and induces an iterative process to solve any inconsistent responses. Ferrari (2003) applied

AHP to choose the best one among different alternative transportation projects.

The rest of the work is divided into 3 sections. Section 2 discusses the review of the literature carried out in this work. The detailed methodology of formulating the decision matrices, normalised matrices and the determination of the priority weights and overall scores is carried out in section 3. Finally, the overall concluding remarks and future scope of the work is discussed in section 4.

REVIEW OF LITERATURE

There are different approaches or models for the quantitative and qualitative evaluation and prioritisation of projects having conflicting objectives. From the literature, it is a fact that there are more than 100 different techniques is proposed by various authors for evaluation and selection of projects (Cooper 1993). The model itself do not make any decisions, people have to do (Meredith and Mantel 2009). According to De Maio *et al*. (1994), no optimal method or technique is used to evaluate and chose the specific project. Project selection is essentially a decision making process carried out by individuals and organisations. The effects of decision making process influence the set of factors under consideration (Reeson and Dunstall 2009). Thompson (1994) showed how AHP can be used to allocate contract incentives among competing and sometimes conflicting project goals by providing an analytic hierarchy methodology by which subjective decisions can be quantified.

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The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach introduced by Saaty (1977). The AHP has created interest of many researchers mainly due to the clear mathematical properties and the fact that required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. The data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance to the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. Some of the industrial engineering applications of the AHP include its use in integrated manufacturing (Putrus, 1990), in the evaluation of technology investment decisions (Boucher and McStravic, 1991), in flexible manufacturing systems (Wabalickis, 1988), layout design (Cambron and Evans, 1991), and also in other engineering problems (Wang and Raz, 1991). The evaluation process of the alternative concepts is a typical multi-criterion decision-making (MCDM) problem, because it involves several criteria (Tuzkaya and Onut, 2008; Ayag and Ozdemir, 2007; Ayag, 2005; Meade and Sarkis, 1999).

The concept of project management stimulates the interest of the companies and shows how the projects are compared by using the application of project management tools and techniques. Though many other industries have bench mark in their operation system, but the project management is lagging in this regard (Ibbs and Kwok, 1998). According to (Prasanta Kumar Dey 2002), various methodology of a benchmark can be described as a search procedure for a best practices leading to the superior performance of an organization in a project management practices.

In the literature, AHP, has been widely used to solve many complicated decision making problems (Chan and Kumar, 2007). The definition of criteria and the calculation of their weight are central in this method to assess the alternatives (Rosaria and Roberto, 2015). The common opinion is that imperfection in specifying the objective is one of the most important reasons for failure of the project (Maciej Nowak, 2013). One of the most important challenges of managers in industry is identification and selection of investment projects, decision making in this regard is faced with some problems (Morteza Yousef ifard, Ebrahim Abbassi and Changiz Val mohammadi, 2015). Analytic Hierarchy Process (AHP) to incorporate quantitative and qualitative factors into the decision (Ping-Yu Chang and Hsin-Yi Lin, 2015). Analytic hierarchy process (AHP) is used to evaluate the competitive priorities of these criteria, and interested organizations can use it as a procedural guidance for implementation (LixinShen, Kamalakanta Muduli and Akhilesh Barve, 2013). The effective use and proper management regarding labour is very important in construction operations without which those activities may not be possible (Rajen B. Mistry, Mr. Vyom B. Pathak and Dr. Neeraj D. Sharma, 2016). For the high acceptability of software projects by the customers, the manufacturing purely depends upon customer demands, budget, and advanced technology (Barinderjit Kaur and Rekha Bhatia, 2015).

In an every new project, it is likely to throw up different issues and challenges faced by the project members. Poor communication, poorly thought out project plan, lack of resources, scope creep, unclear objectives, no stakeholder buy in etc., are the few challenges to be resolved to achieve the best business strategy in an organisation. Under these circumstances, project management plays a crucial role in the overall business activity and helps to classify the concepts into several categories. Also, the project management ensures the smooth continuation of the work. A change in the nature of the project can be the most difficult and disruptive type of challenge.

Based on the literature review, it is suggested that proper selection criteria should be used as a basis for analysing and comparing projects. The process of projects selection includes quantitative and qualitative type, financial and non-financial type and also suggested that the criterion differs for each industrial sector.

Meredith and Mantel (2009) propose criteria for choosing a selection model and suggest the kinds of information required to evaluate the projects. Strategic project selection for manufacturing industry identifies the wide range of project selection criteria for different types of projects. Choosing the wrong projects can lead to project failure in various aspects. Selecting and prioritising projects in line with strategy (Muller, Martinsuo *et al*. 2008) and the importance of strategic alignment and defined need are also emphasised by Murray, Burger *et al*. (2009).

Unlike all the aforementioned articles, this paper considers five different projects in the perspective of manufacturing industrial sector. The set of factors: Realism, Capability, Flexibility, Ease to use, Cost and Ease are considered to evaluate the projects. Using AHP, the pairwise comparison matrix is prepared for all the six set of factors under consideration using Saaty's scale and finally the global weights of five different projects are computed.

METHODOLOGY

Structure the decision hierarchy

In this paper, five different projects: project 1, project 2, project 3, project 4 and project 5 are considered in manufacturing industrial scenario. For evaluation and selection of these projects, six set of factors: Realism, Capability, Flexibility, Easy to use, Cost and Easy to computerization are considered. Figure-1 demonstrates the hierarchical structure of the model representing the number of levels involved in the problem. Level 1, level 2 and level 3 indicate the overall objective of the problem, the set of criteria used, and the decision alternatives respectively.

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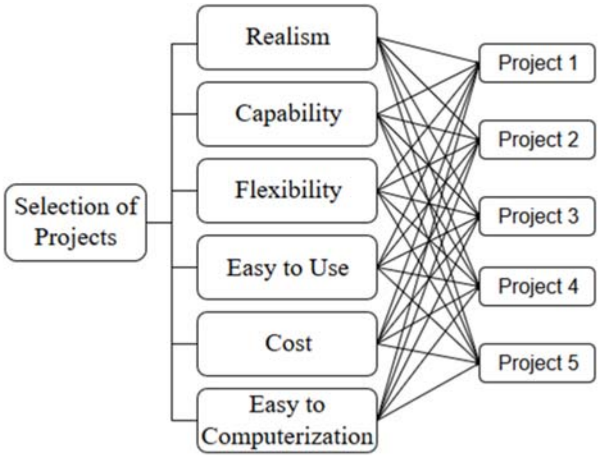

Figure-1. Overview of project selection.

In general, the decision of project selection should include the reality of the multiple objectives of both the firm and its managers. Without the use of any common measurement system, it is very difficult for direct comparison of different projects. The consideration of project risks, technical risks, cost, time, and market risks are said to be more important while evaluating multiple projects. The capacity of the manufacturing firm should be sufficient enough to simulate various internal and external situations of a project and to optimize the decision of project selection. Also, the firm has to consider the major set of risks and constraints of projects.

The range of conditions that the firm experiences in future must be flexible enough. Also, should be easily modified, or to be self-adjusting in response to changes in firm environment. Ease of use is another important criterion in evaluation and selection of projects. Project evaluation should not involve special interpretation, data that is said to be very difficult to get, excessive personnel, unavailable equipment. Also, the process of project selection should be easy to simulate the desired out comes associated with project investment. Further, the cost of data collection and modelling should be low compared to the cost as well as potential benefits of the project. Also, information gathering and storage in a computer data base must be convenient and easy. Thus, the evaluation and selection of projects under multiple goals is a challenging and worthwhile in nature.

Construct a Set of Pairwise Comparison Matrices Based on Saaty's fundamental scale; the decision matrix is formulated for the six criteria under consideration. From the decision matrix, the normalized matrix is determined. Then, the priority weights of all six criteria are determined. These priority weights are helpful in determining the contribution of each criterion towards the final objective of the parental organization. Further, to verify the consistency of the decision matrix of all the six criteria, the consistency ratio is calculated as shown below.

The values are chosen/collected/ calculated based on expertise persons in the manufacturing industrial sector for this decision matrix.

Table-1. Decision matrix for the six criteria.

FACTOR	**C1**	**C2**	**C3**	**C4**	**C4**	**C6**
C1	**1.00**	**7.00**	**3.00**	**1.00**	**1.00**	**1.00**
C2	0.14	1.00	0.14	0.20	0.20	0.16
C3	0.33	7.00	1.00	1.00	1.00	3.00
C4	1.00	5.00	1.00	1.00	1.00	5.00
C5	1.00	5.00	1.00	1.00	1.00	4.00
C6	1.00	6.00	0.33	0.20	0.25	1.00
Total	4.47	31.00	6.50	4.40	4.50	14.20

Based on the decision matrix the normalised matrix is prepared by sum for values by total sum based on priority weights.

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Table-2. Normalize matrix for the six criteria.

F	C1	C2	C3	C4	C4	C6
C1	**0.2234**	**0.2258**	**0.4632**	**0.2273**	**0.2247**	**0.0706**
C2	0.0319	0.0323	0.0221	0.0455	0.0449	0.0118
C3	0.0745	0.2258	0.1544	0.2273	0.2247	0.2118
C4	0.2234	0.1613	0.1544	0.2273	0.2247	0.3529
C5	0.2234	0.1613	0.1544	0.2273	0.2247	0.2824
C6	0.2234	0.1935	0.0515	0.0455	0.0562	0.0706

With the help of normalized matrix shown in Table-2, the priority weights for all the six criteria are determined as shown below.

$$w_1 = \frac{0.2234 + 0.2258 + 0.4632 + 0.2273 + 0.2247 + 0.0706}{1.4350} = 0.2392$$

$$w_2 = \frac{0.0319+ 0.0323+ 0.0221+ 0.0455+ 0.0449+ 0.0118}{0.1884} = 0.0314$$

$$w_3 = \frac{0.0745+ 0.2258 +0.1544 +0.2273+ 0.2247+ 0.2118}{1.1184} = 0.1864$$

$$w_4 = \frac{0.2234+ 0.1613+ 0.1544+ 0.2273+ 0.2247+ 0.3529}{1.1184} = 0.2240$$

$$w_5 = \frac{0.2234+ 0.1613+ 0.1544+ 0.2273+ 0.2247+ 0.2824}{1.2735} = 0.2122$$

$$w_6 = \frac{0.2234+ 0.1935+ 0.0515+ 0.0455+ 0.0562+ 0.0706}{0.6406} = 0.1068$$

Next, the consistency ratio is calculated to verify the consistency of the decision matrix of all the six criteria as shown below.

Step 1: Determine the vector Aw^T

$$Aw^T = \begin{bmatrix} 1.00 & 7.00 & 3.00 & 1.00 & 1.00 & 1.00 \\ 0.14 & 1.00 & 0.14 & 0.20 & 0.20 & 0.16 \\ 0.33 & 7.00 & 1.00 & 1.00 & 1.00 & 3.00 \\ 1.00 & 5.00 & 1.00 & 1.00 & 1.00 & 5.00 \\ 1.00 & 5.00 & 1.00 & 1.00 & 1.00 & 4.00 \\ 1.00 & 6.00 & 0.33 & 0.20 & 0.25 & 1.00 \end{bmatrix} \begin{bmatrix} 0.2392 \\ 0.0314 \\ 0.1864 \\ 0.2240 \\ 0.2122 \\ 0.1068 \end{bmatrix} = \begin{bmatrix} 1.5612 \\ 0.1953 \\ 1.2417 \\ 1.5528 \\ 1.4460 \\ 0.6937 \end{bmatrix}$$

Step 2: Compute $\frac{1}{n}\sum_{i=1}^{i=n} \frac{i^{th} entry\ in\ AW^T}{i^{th} entry\ in W^T}$

$$= \left(\frac{1}{6}\right)\left\{\frac{1.5612}{0.2392} + \frac{0.1953}{0.0314} + \frac{1.2417}{0.1864} + \frac{1.5528}{0.2240} + \frac{1.4460}{0.2122} + \frac{0.6937}{0.1068}\right\} =$$
6.62015

Step 3: Compute the Consistency Index (CI)

$$CI = \frac{(Step2\ Result) - n}{n-1}$$

$$\text{CI} = \frac{6.62015 - 6}{5} = 0.1240$$

Step 4: Comparison of Consistency Index (CI) to the Random Index (RI) for the appropriate

Value of n, where Aw^T = n and $a_{ij} = \frac{1}{a_{ji}}$

From the Ratio Index Table, the value of the Ratio Index, RI= 1.1240

$$CR = \frac{CI}{RI} = \frac{0.1287}{1.1240} = 0.1145$$

In the similar manner, the decision matrix, normalized matrix and the value of consistency ratio is computed for all five alternative projects with respect to each criterion as shown below.

Table-3. Decision matrix of five alternatives w.r.t Criterion C1 (Realism) the pairwise matrix have been prepared with the help of analytic process.

FACTOR	P1	P2	P3	P4	P5
P1	1.00	7.00	3.00	1.00	1.00
P2	0.14	1.00	0.14	0.20	0.20
P3	0.33	7.00	1.00	1.00	1.00
P4	1.00	5.00	1.00	1.00	1.00
P5	1.00	5.00	1.00	1.00	1.00
Total	3.47	25.00	6.14	4.20	4.20

Table-4. Normalized matrix of five alternatives w.r.t Criterion C1 using pairwise the normalised matrix have been evaluated to find the priority weights with respect to realism.

F	P1	P2	P3	P4	P5	PW
P1	0.288	0.280	0.488	0.238	0.238	0.306
P2	0.041	0.040	0.023	0.048	0.048	0.040
P3	0.096	0.280	0.163	0.238	0.238	0.203
P4	0.288	0.200	0.163	0.238	0.238	0.225
P5	0.288	0.200	0.163	0.238	0.238	0.225

Note: Priority Weights (PW)

The value of Consistency Ratio = 0.0375 for C1 with respect of P1 is highest score and P2 is least score.

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Table-5. Decision matrix of five alternatives w.r.t Criterion C2 (Capability).

FACTOR	P1	P2	P3	P4	P5
P1	1.00	8.00	2.00	1.00	4.00
P2	0.12	1.00	0.12	0.20	0.20
P3	0.50	8.00	1.00	1.00	1.00
P4	1.00	5.00	1.00	1.00	1.00
P5	0.25	5.00	1.00	1.00	1.00
Total	2.87	27.00	5.12	4.20	7.20

Table-6. Normalized matrix of five alternatives w.r.t Criterion C2.

F	P1	P2	P3	P4	P5	PW
P1	0.348	0.296	0.390	0.238	0.556	0.366
P2	0.043	0.037	0.024	0.048	0.028	0.036
P3	0.174	0.296	0.195	0.238	0.139	0.208
P4	0.348	0.185	0.195	0.238	0.139	0.221
P5	0.087	0.185	0.195	0.238	0.139	0.169

The consistency Ratio = 0.0443

For all other criterion for the consideration for project selection with the techniques of analytic hierarchy process.

Table-7. Decision matrix of five alternatives w.r.t Criterion C3 the decision matrix is evolved to find normalise matrix base on expertise opinion.

FACTOR	P1	P2	P3	P4	P5
P1	1.00	6.00	3.00	4.00	8.00
P2	0.16	1.00	0.14	0.20	0.20
P3	0.33	7.00	1.00	1.00	1.00
P4	0.25	5.00	1.00	1.00	1.00
P5	0.12	5.00	1.00	1.00	1.00
Total	1.87	24.00	6.14	7.20	11.20

Table-8. Normalized matrix of five alternatives w.r.t Criterion C3.

F	P1	P2	P3	P4	P5	PW
P1	0.533	0.250	0.488	0.556	0.714	0.508
P2	0.089	0.042	0.023	0.028	0.018	0.040
P3	0.178	0.292	0.163	0.139	0.089	0.172
P4	0.133	0.208	0.163	0.139	0.089	0.147
P5	0.067	0.208	0.163	0.139	0.089	0.133

Consistency Ratio = 0.0798

Table-9. Decision matrix of five alternatives w.r.t Criterion C4.

FACTOR	P1	P2	P3	P4	P5
P1	1.00	3.00	2.00	3.00	6.00
P2	0.33	1.00	0.14	0.20	0.20
P3	0.50	6.00	1.00	1.00	1.00
P4	0.33	4.00	1.00	1.00	1.00
P5	0.16	5.00	1.00	2.00	1.00
Total	2.33	19.00	5.14	7.20	9.20

Table-10. Normalized matrix of five alternatives w.r.t Criterion C4.

F	P1	P2	P3	P4	P5	PW
P1	0.429	0.158	0.389	0.417	0.652	0.409
P2	0.143	0.053	0.028	0.028	0.022	0.055
P3	0.214	0.316	0.194	0.139	0.109	0.194
P4	0.143	0.211	0.194	0.139	0.109	0.159
P5	0.071	0.263	0.194	0.278	0.109	0.183

Consistency Ratio = 0.1439

Table-11. Decision matrix of five alternatives w.r.t Criterion C5.

FACTOR	P1	P2	P3	P4	P5
P1	1.00	4.00	2.00	3.00	5.00
P2	0.25	1.00	0.14	0.20	0.20
P3	0.50	4.00	1.00	1.00	1.00
P4	0.33	8.00	1.00	1.00	1.00
P5	0.20	2.00	1.00	1.00	1.00
Total	2.28	19.00	5.14	6.20	8.20

Table-12. Normalized matrix of five alternatives w.r.t Criterion C5.

F	P1	P2	P3	P4	P5	PW
P1	0.438	0.211	0.389	0.484	0.610	0.426
P2	0.109	0.053	0.028	0.032	0.024	0.049
P3	0.219	0.211	0.194	0.161	0.122	0.181
P4	0.146	0.421	0.194	0.161	0.122	0.209
P5	0.088	0.105	0.194	0.161	0.122	0.134

Consistency Ratio = 0.0423

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Table-13. Decision matrix of five alternatives w.r.t Criterion C6.

FACTOR	P1	P2	P3	P4	P5
P1	1.00	4.00	2.00	3.00	2.00
P2	0.25	1.00	0.14	0.20	0.20
P3	0.50	4.00	1.00	1.00	1.00
P4	0.33	8.00	2.00	1.00	1.00
P5	0.50	2.00	1.00	1.00	1.00
Total	2.58	19.00	6.14	6.20	5.20

Table-14. Normalized matrix of five alternatives w.r.t Criterion C6.

F	P1	P2	P3	P4	P5	PW
P1	0.387	0.211	0.326	0.484	0.385	0.358
P2	0.097	0.053	0.023	0.032	0.038	0.049
P3	0.194	0.211	0.163	0.161	0.192	0.184
P4	0.129	0.421	0.326	0.161	0.192	0.246
P5	0.194	0.105	0.163	0.161	0.192	0.163

Consistency Ratio = 0.0631

Finally, the overall score for each of the five alternative projects is computed and tabulated as shown in Table-15.

P1= 0.2392(0.306) + 0.0314(0.366) + 0.1864(0.508) +0.2240(0.409) +0.2122(0.426) +0.1068(0.358) = 0.3996
P2= 0.2392(0.040) + 0.0314(0.036) + 0.1864(0.040) +0.2240(0.055) +0.2122(0.049) +0.1068(0.049) = 0.0461
P3= 0.2392(0.203) + 0.0314(0.208) + 0.1864(0.172) +0.2240(0.194) +0.2122(0.181) +0.1068(0.184) = 0.1886
P4= 0.2392(0.225) + 0.0314(0.221) + 0.1864(0.147) +0.2240(0.159) +0.2122(0.209) +0.1068(0.246) = 0.1943
P5= 0.2392(0.225) + 0.0314(0.169) + 0.1864(0.133) +0.2240(0.183) +0.2122(0.134) +0.1068(0.163) = 0.1707

Based on the overall weight it is concluded that the project score of the optimal weight states that project 1 is acceptable for the manufacturing sector.

Table-15. Summary of the overall score.

Weight	S1	S2	S3	S4	S5	S6	Overall score
Projects	**0.2392**	**0.0314**	**0.1864**	**0.2240**	**0.2122**	**0.1068**	
P1	0.306	0.366	0.508	0.409	0.426	0.358	0.3996
P2	0.040	0.036	0.040	0.055	0.049	0.049	0.0461
P3	0.203	0.208	0.172	0.194	0.181	0.184	0.1886
P4	0.225	0.221	0.147	0.159	0.209	0.246	0.1943
P5	0.225	0.169	0.133	0.183	0.134	0.163	0.1707

Hence AHP would indicate that Project 1 is Acceptable

CONCLUSIONS

This paper is attempted to evaluate and select a best project in manufacturing industrial scenario using Analytic Hierarchy Process (AHP). Five different projects: project 1, project 2, project 3, project 4 and project 5 are chosen in this work. To evaluate all these five projects, six criteria: Realism, Capability, Flexibility, Easy to use, Cost and Easy to computerization are considered. Based on these five projects and six criteria, the hierarchical structure of the model is developed with three levels where level 1 represents objective of the work, level 2 shows set of criteria under consideration and level 3 indicates five alternative chosen projects. In this work, initially, the decision matrix is formulated for all the six set of criteria with respect to the overall objective. Next, the normalized matrix is prepared based on the decision matrix of the six criteria and then the vector of priority weights is determined. Also, the value of the consistency ratio is determined to verify the consistency of the decision matrix of the six criteria. Similarly, with respect to each criterion, the decision matrices, normalised matrices, vectors of priority weights and the values of consistency ratio are computed. Finally, the overall scores for all five projects are calculated.

Based on the findings of this paper, it is concluded that the first criterion (Realism) is most prioritized and the second criterion (Capability) is least prioritized out of all the six criteria. Further, it is concluded that project P1 scored maximum weight and project P2 scored minimum weight with respect to each of the six criteria. Also, it is concluded that project P1 is most prioritized as it obtained maximum overall score whereas project P2 is least prioritized.

The findings of this research support the management in choosing a reliable project of manufacturing area for capital investment. In future, the inquisition method can be generalized into all manufacturing sectors for selection of projects.

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