

A Case Base Approach for Evaluation of Manufacturing Effectiveness of a Firm Using Analytical Hierarchical Process

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Abstract - High level of Manufacturing Capability (MC) (effectiveness) plays significant role in providing competitive advantage to a firm. However, it is difficult for the firm to evaluate the level of MC, which is given by the consistency of decisions taken in the particular manufacturing environment. For example, in job shop production general purpose facilities and high skilled workforce is essential to obtain the desired level of outputs to satisfy customer expectations. First, Hayes and Wheelwright provided a four stage model to define the level of MC and recently Miltenburg gave a framework that classified these four stages as infant, average, adult and world class. Evaluating MC facilitates the firm to know the present status and also provides a pointer to identify weak decisions for further improvement. The main contribution of this research is to presents a case study on evaluating the MC in order to find the weak decision areas of a firm involved in the Job Shop Production System. Objective of this research is to find out the current status (level) of MC of a firm based on the consistency of the decisions taken. For this, hierarchical model based on the overall goal as a MC index has been developed by using Analytical Hierarchical Process (AHP) – a Multi Criteria Decision Making (MCDM) tool. The MC index of a firm under consideration is computed by evaluating the pattern of decisions taken in the manufacturing which are obtained after discussion with top executives of the company. The results obtained are then compared with ideally required decisions from the same category of manufacturing. Based on the comparison, status (level) of MC and weak decision areas of the firm have been identified and discussed with the executives for the further improvements.

Keywords: Manufacturing strategy, Job Shop Production System (JSPS), Competitive advantage, Competitive priorities, Decision areas and AHP.

1 Introduction:

In the present era manufacturing companies are facing tremendous pressure of competitive edge in terms of new product, new processes and new emerging technology. To

cope with these challenges such as low cost or high differentiation and to be competitive in the market they must know their manufacturing effectiveness of their manufacturing processes [1]. MC can be defined in terms of the level of their manufacturing outputs (competitive priorities) like cost, quality, delivery, flexibility, performance and innovations which is depends upon the pattern of decisions areas of the manufacturing system [2]. These decision areas mainly divided in to two categories which are structural and infrastructural [3]. Literature has given various classifications of these decision areas under heading of structural and infrastructural category. [1,4,5,6,7]. According to Miltenburg [1] the decisions related to structural categories are Human Resources (HR), Organization Structure and Control (OSC), Production Planning and Control (PPC), and infrastructural categories are Process Technology (PT), Sourcing (SC) and Facility (FY) which is used in this work. These decision areas are also referred as manufacturing sub-system or manufacturing lever and adjustment to these levers affects the manufacturing outputs provided by the production system [1]. Authors [1,8] argues that setting or choices made in each area decides the MC of the production system which in turn decides level of the competitive priorities. Therefore a role of each decision areas needs to be understood in depth to evaluate the MC of the system in order to gain a competitive advantage. However, the importance of manufacturing functions has generally ignored by the top management and investment in manufacturing related functions is looked at a liability to the company [9,10]. Skinner [9] emphasized the importance of manufacturing and its linking with corporate functions to achieve competitive advantages. Further in order to compete on the basis of competitive priorities Skinner [4] suggested the framework of focused factory. The basic idea of the focused factory is stop compromising at every stage of manufacturing system, and concentrate only on the key decision areas.

Choudhary et al. [8] developed research framework to identify decision choices (attributes) for each decision areas of all manufacturing systems for fifty four decision criteria. Further Choudhary et al. [11,12,13] done exploratory study to identify decision choices for the corresponding decision areas for the job shop, batch shop and line shop using a case study approach. Jain [10] also presented a work on

measurement of strategic effectiveness using Hayes and Wheelwright Model. The findings of their work were exploratory and cannot be practiced as well as not supported by any empirical analysis. Therefore a conceptual hierarchical model with six decision area, thirty three decision criteria and hundred an eight decision choices has developed and empirically tested with the help of live industrial case of JSPS. A case study methodology which gives true and scientific research approach to understand and analyze the decision area is followed in this work [14]. The rest of the paper is organized as follows. Section 2 reviews the relevant literature and identified literature gap. Section 3 presents a research methodology carried for understanding and analyzing the decision areas for low volume and high variety production system (JSPS). Section 4 dealt with case study and its analysis and concluding remark is presented in section 5.

2. Literature Review:

First time, Hayes and Wheelwright [3,15] have defined an effectiveness of a firm into four stages. Stage 1 internally neutral, stage 2 externally neutral, stage 3 internally supportive and stage 4 externally supportive. Whereas Miltenburg [1] redefined this MC (effectiveness as Level 1: Infant, Level 2: Average, Level 3: Adult and Level 4: World class. Hum and Leow [16] developed a questionnaire using five point rating scale based on the work of Hayes et al [5] on certain decision areas. However, in their work they have compared the characteristics of stage 2 and 4 only using survey based methodology with response rate of 27.5% and no attempt has been made for stage 1 and 3. Rowbatham and Barnes [17] has operationlized the questionnaire about the cross case study of three organizations and concluded that further research is required on questionnaire as an instrument for exploring the concept of H-W (Hayes and Wheelwright) model [15]. Later, Barnes and Rowbatham [18] have modified the questionnaire and applied those on 390 UK organizations using survey method and argue about the utility and validity of the H-W model also stated that a very few attempt has been made about the empirical analysis. Authors again argue that a questionnaire developed in the literature was not logical as far as full ranges of decision areas are concerned. They have also raised the question about published literatures on classification of organization with four stage model. However, in spite of the simplicity and wide spread acceptance of this concept a very few research work has been reported about the practical implementation of this concept [18,10]. Jain et al. [10] also developed a questionnaire as an instrument on 14 measures and tested on 28 Indian manufacturing units which raise the questions about its validation. Dangayach and Deshmukh [19] have also studied this model in Indian context for five automobile companies with help of 19 attributes related to the different stages. Finally, above mentioned literature concluded that further research is required in order to develop an instrument to explore the concept of four stage model to evaluate the effectiveness.

This work is an attempt to conduct the case study based on detailed empirical analysis in order to fill the gap in literature explained above. The novelty of this work is the development and the practical implementation of AHP based conceptual model to evaluate the capability of the manufacturing system. For empirical testing and implementation of the concept presented in this model an AHP base questionnaire has been prepared to convert the qualitative judgment into the quantitative values on the six decision areas suggested by Miltenburg [1]. The detailed research methodology carried out in this work is given in the next section.

3. Research Methodology

Several studies [20,21,22,23,11] emphasized the importance of case study approach for analysis of the production systems. This approach helps the researchers to reduce the gap between theory and practices by recognizing and understanding how and why events occur. The methodology followed during this research work is started with literature review on identification of decision areas, decision criteria and its respective attributes followed by the development of a conceptual hierarchical model (Figure 1). An ideal decision has been finalized form the literature to define ideal manufacturing system. Ideal system means, the system having maximum level attribute of the relevant decision criteria. For example in case of JSPS high level skill is required to satisfy high variety of product, therefore high skilled level is taken as ideal decision attribute for level of skill in HR decision area. In similar way ideal decision has attributes has decided for all thirty-three decision criteria. An AHP base closed ended questionnaire has been prepared for conduction of structured interview [24]. Next is the identification of suitable case company for implementation of this concept. Computation of MC score and compare with the ideal manufacturing system to find the deviation of practical inferences which helps in identification of weak decision areas for improvements. At last, suggestion of relevant manufacturing practices/programmes for improvements of the weak decision to enhance the level of MC in order to match with ideal case.

4. Case Study:

4.1 About case company

The case study has been carried out for firm located in Mumbai, Maharashtra state (hereafter referred to as ABC). ABC firm manufactures Indian boiler, chemical process equipment, heat exchanger, reactors, storage tank, heat exchanger, filters which supplies to chemical, pharmaceutical and food processing industries. The company procures small accessories, electronic components,

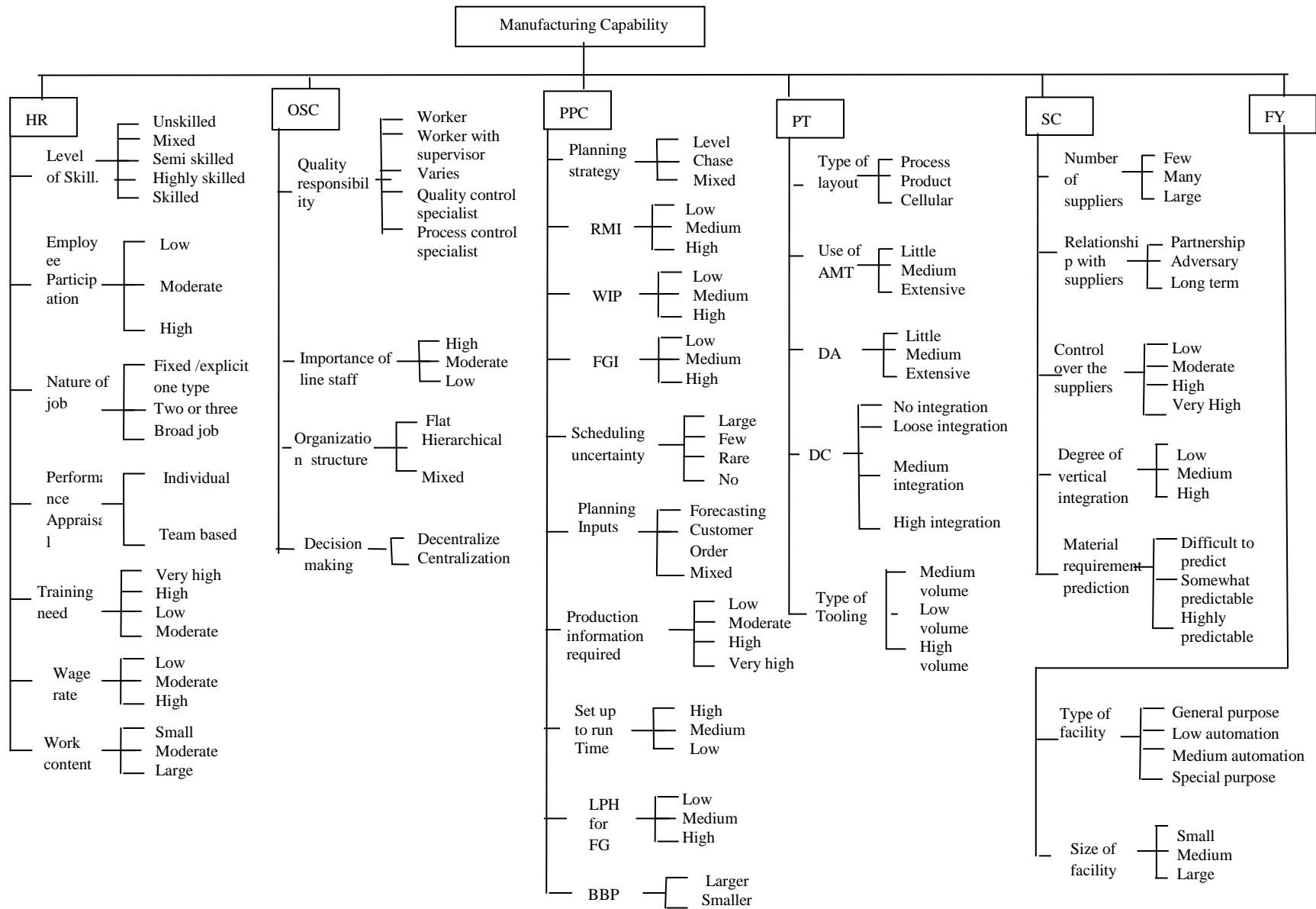


Figure 1 An AHP based conceptual model to evaluate the manufacturing capability of JSPS

and raw materials from vendors and makes 90% of components in house.

4.2 Data collection

The first point of contact in the company was the Assistant general manager (manufacturing) and further he then introduced with Assistant manager. We initially explained them research objective, details of the information required, possible people of the company required for the interaction. A data for this case study is collected by conducting structured interview with shop supervisor, Assistant manager and top management of this company using closed ended AHP based questionnaire. A sample of filled questionnaire form is given in Table 1

4.3 AHP based capability assessment.

The overall manufacturing capability of an ABC Company is obtained by using the formula

$$S = \sum_{i=1}^6 \sum_{j=1}^6 \sum_{k=1}^6 W_i w_{ij} P_{ijk} \dots \dots \dots 1$$

Where: S is the overall manufacturing capability index of the firm; W_i is the importance (weight) of the i^{th} decision area; w_{ij} is the relative importance j^{th} decision belonging to the i^{th} decision area. P_{ijk} is the rating value of decision choice of the firm for the j^{th} decision belonging to the i^{th} decision area. The model consists of six decision areas, 33 decision criteria and 108 decision attributes. The relative importance of the decision area and decisions belonging to each decision area were obtained by using AHP, where the input for this were obtained from the production head through a systematic questionnaire. The sample computation of relative importance for six decision areas is shown in Table 2. For example refer the first row of the Table 2, as per production head HR is moderately strong importance over organization structure therefore, 4 point is given whereas it is having moderate importance over PPC where 3

points have given. Similarly pair wise comparison for all the decision areas has been carried and the relative weights for the areas is calculated by taking the n^{th} root of the product of n elements ($n = 6$ in this case) in each row and then normalizing the resulting values. Computations were revised in consultation with the production head to arrive at the desired consistency. The consistency ratio for this comparison is 3.5%, which is within the acceptable limit of 10%. In this case study, HR received the highest relative weight (36.3%) followed by PT and PPC (20.9%), (20.7%) respectively, decision area received lowest importance of 4.5% to OSC. A similar process is followed in calculating the relative weights for all criteria belonging to each group, as well as weights to the groups themselves. Similarly, data for importance of decision choices for a given decision belonging to a particular decision area were obtained by asking questions to the production head which was based on rating approach. For example, to understand the choice for operator skill (decision – level of skill in decision area human resources) that is required to produce the customer specific product the question asked was “what level of skill is deployed for the required output” and the options were provided which were rated on the scale of 0 to 10 [25]. For example, the skill required rated 10 for highly skilled requirement, and 7 for mixed, 5 for skilled, 3 for semi skilled and 0 for unskilled. Similarly all the inputs required to assess the capability of a firm was obtained. Excerpt of the capability assessment model for human resources decision area is shown in Table 3. It consists of seven decisions (criteria); these are skill level, nature of job, performance appraisal, training need, employee participation, wage rate and work content of a job. Decision consistency in a particular production system is very much essential to have high level of manufacturing effectiveness. Therefore, decision choice made under each decision area can have a great influence on manufacturing competitiveness. Further detailed analysis of the case under study is presented in the following sub-section.

Table 1 Importance of one group criteria over other

Attributes for Group criteria	Equally preferred (1)	Equally to moderately preferred (2)	Moderately preferred (3)	Moderately to strongly preferred (4)	Strongly preferred (5)	Strongly to very strongly preferred (6)	Very strongly preferred (7)	Very strongly to extremely preferred (8)	Extremely preferred (9)	Attributes for Group criteria
HR				4						OSC
HR			3							PPC
HR			3							PT
HR				4						SC
HR			3							FY
OSC					1/5					PPC
OSC				1/4						PT
OSC				1/4						SC
OSC		1/2								FY
PPC	1									PT
PPC			3							SC
PPC			3							FY
PT				4						SC
PT			3							FY
SC			3							FY

Table: 2 Computation of relative weights of Decision areas

	Human Resources	Organization structure and control	Production planning and control	Process Technology	Sourcing	Facility	Relative weight
Human Resources	1.00	4.00	3.00	3.00	4.00	3.00	0.36
Organization structure and control	0.25	1.00	0.20	0.25	0.25	0.50	0.04
Production planning and control	0.33	5.00	1.00	1.00	3.00	3.00	0.21
Process Technology	0.33	4.00	1.00	1.00	4.00	3.00	0.21
Sourcing	0.25	4.00	0.33	0.25	1.00	3.00	0.15
Facility	0.33	2.00	0.33	0.33	0.33	1.00	0.07

Table 3. Excerpt of capability assessment for human resources decision area

Decision Area	Weight	Decisions Criteria	Weights	Effective Weight	Decision Choice - For Ideal Job Shop	Rating Value Of Decision Choice For Ideal Case	Decision Choice	Rating Of Decision Choice For ABC Company	Performance Of ABC	Performance - (Likely To Be Job Shop)
HR	0.363	Level of Skill	0.4	0.14	High Skill	10.00	High Skill	10.00	1.44	1.44
		Employee Participation	0.13	0.045	High	10.00	High	10.00	0.47	0.48
		Nature of Job	0.15	0.06	Broad	10.00	Broad Job	10.00	0.56	0.56
		Performance Appraisal	0.14	0.05	Individual	10.00	Individual	10.00	0.51	0.51
		Training Need	0.05	0.02	Moderate	10.00	Low	7.00	0.14	0.20
		Wage Rate	0.07	0.03	High	10.00	High	10.00	0.27	0.27
		Work Content	0.05	0.027	Large	10.00	Large	10.00	0.17	0.17

4.4 Case analysis

The overall MC index of this company is found to be 8.47 using the equation 1 given in the last sub-section while that of likely to be the ideal decisions is 10. For further improvement we have identified the weak decision areas by comparing company’s decisions areas with likely to be the ideal system. Figure 2 shows Percentage gaps of decision areas. ABC Company has maximum gap of 48% in PT, followed by 26% for SC and 18 % for PPC. Our analysis shows that major inconsistency is observed for decisions in PT decision areas therefore the major changes are required to be done for PT decision area to enhance the level of MC of ABC Company. We further drill down and it observed that small changes are required to be carried over for the other two decision areas i.e. SC and PPC. To further improve the competitiveness of the decisions in PT decision area needs to be addressed on a priority basis. For example, the firm should start using the Advanced Manufacturing Technology (AMT) in design and manufacturing as well as process planning which will affect positively on the quality of the product. The detailed analysis supports in identification and prioritization of decisions and decisions to

further improve the MC and hence the competitiveness. From figure 2, we can also say that most of decisions in the decision areas, like HR, OSC, and facilities are in line with the likely to be the ideal decisions in the job shop manufacturing environment whereas the decision area of PT

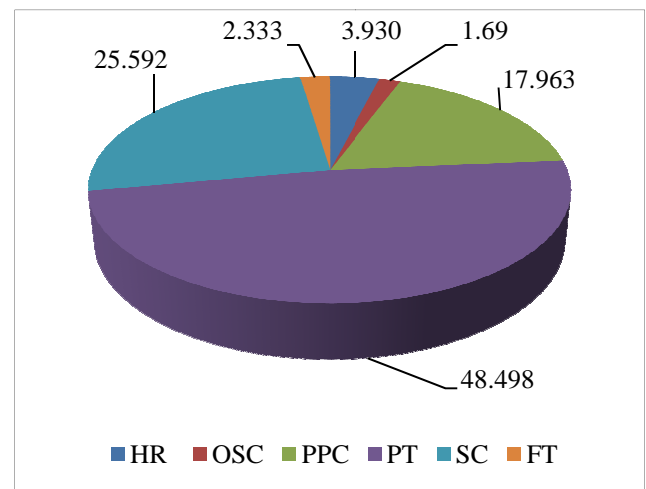


Figure 2 Percentage gaps of decision areas.

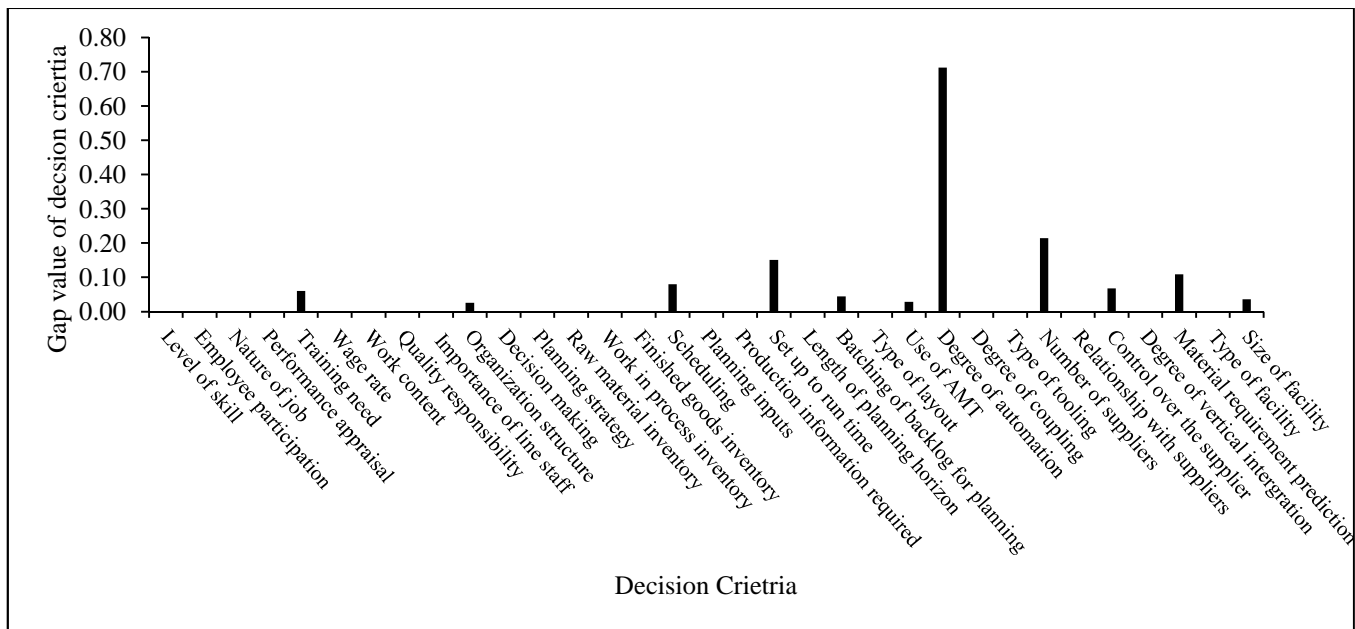


Figure 3 Gap analysis of decision criteria for ABC Company

goes beyond boundary of ideal system. Further, the detailed analysis of all 33 criteria has been carried out by comparing these criteria with ideal case criteria from the same category of manufacturing system and gap analysis has been carried out which is shown in figure 3. Out of 33 decision criteria total 11 mismatches were found. From 11 mismatches, 5 mismatches correspond to infrastructural issues and 6 correspond to structural issue. The mismatch decision criteria corresponds to infrastructural category are training needs, organization structure, scheduling, set up to run time, and batching the backlog. Whereas, use of AMT, degree of automation, number of supplier, control over the supplier, material requirement prediction, size of facility related to structural category. Company ABC has needs to treat these 11 decision criteria properly in order to enhance the level of manufacturing capability and hence its manufacturing outputs.

5. Conclusion:

A systematic case based approach to evaluate MC of ABC Company using AHP a MCDM tool has been dealt in this work. This approach will help the practitioners' to identify the weak decision area to improve the level of capability of their existing manufacturing system For this, total 33 decisions (criteria) and their corresponding choices (attributes) have been identified from the literatures which are classified into six decision areas. Analysis suggested the overall capability of ABC Company is 8.47 in a scale of 0 to 10 that means the case company is 84.7% efficient. The mismatches observed in that analysis validates with the existing available literature that capability is more depended on infrastructural issue than that of structural [1,26]. In addition to the quantification of overall MC of a firm, this approach facilitates further analysis at the decision area level by indicating the contribution of each decision area

(given by each decision choice) in comparison with likely to be the ideal decision choices. This helps in pointing out weak decision areas and decisions which can be fine-tune for further improving the competitiveness of a firm. The proposed model needs to be tested in the field for different JSPS to strengthen the outcome of this research work. The values obtained in this work can be used as a benchmarking the decision making in manufacturing environment. The finding of this work can be used to find the strategic orientation of the company using Hayes and Wheelwright model [15]. Future researchers can develop a framework for finding out the appropriate manufacturing programme/practices to enhance the level of weak decisions

Acknowledgment

The authors express a sincere thanks to the production head and all staff of the ABC Company for all their constant help and support for completing this work. The authors also express their special to top management for permitting them to carry out this study.

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