Manufacturing Capability Evaluation in a Job Shop Production System: A Case Base Approach

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Abstract: **Paper analyzes manufacturing capability in job shop environments by evaluating the pattern of decisions using a case study approach. Analytical Hierarchical Process (AHP), a multi criteria decision making (MCDM) method, has been employed which consists of three levels. The overall goal, i.e. manufacturing capability index is placed at level 1 followed by six decision areas at level 2 and thirty three decision criteria at level 3. Structured interview process has been used to collect information about thirty three decision criteria. The data was collected and analyzed for five companies operated in a job shop manufacturing environment. Pattern of decisions that are ideally essential for competitiveness of job shop manufacturing are then compared with the pattern of decisions from the five cases. This approach facilitates the practitioners to indentify the weak decision areas in order to improve the competitiveness in job shop manufacturing.**

Keywords: Manufacturing strategy, Job shop production system, Competitive advantage, Competitive priorities, Decision areas, Analytical hierarchical process.

I. INTRODUCTION

Manufacturing firms compete in the market on either the cost or differentiation [1]. This translates the requirement to the manufacturing which can be fulfilled by producing the outputs like cost, quality, delivery and flexibility as expected by the customers. A number of studies have shown that a manufacturing strategy helps firms in improving their competitive position in the market [2, 3, 4, 5]. Manufacturing strategy is an approach to achieve long term competitive advantage and it has received considerable attention in the literature [6]. It consists of a pattern of decisions relating to the different sub-systems of manufacturing which are referred as structural and infrastructural [7, 8, 9, 10]. Structural decisions include, process technology (PT), sourcing (SC) and facility (FY) while infrastructural decisions include, human resources, organization structure and control (OSC) and production planning and control (PPC) [1]. Manufacturing capability is an essential element of manufacturing strategy. It can be defined as the ability to compete on the basic dimensions (competitive priorities) such as quality, cost, flexibility and time. Competitive priorities deals with importance while manufacturing capability deals with performance [11]. Proper alignment of manufacturing capability with the business strategy significantly improves the competitive strength of the manufacturing firm [12].

Manufacturing system provide the required competence to excel business competitive priorities in the market based on the consistency of decisions taken in the

manufacturing environment [11, 13, 14]. In 1997 Ghalayini et al. [15] argued that till 1980 manufacturing performance was solely based on traditional cost accounting system to monitor,
control and improves it. He further suggested an integrated dynamic performance measurement system for improving the manufacturing competitiveness. To improve the manufacturing performance the firm must know the capability in terms of outputs such as cost, quality, delivery, etc. [2,3]. It is well documented that the firm cannot produce all the manufacturing outputs at highest possible level as it involves trade-off [16].
Skinner [7] suggested a focused factory concept, focusing manufacturing on one of the areas based on company's competitive priority.

This paper presents a case based approach to understand and analyze the pattern of decisions taken by the job shop manufacturing companies for their competitiveness by using a multi-criteria approach in assessing the manufacturing capability. The remainder of the article is organized as follows: section II presents literature pertaining to manufacturing capability, and its assessment. Section III outlines the research methodology whereas, section IV illustrates within case analysis of five cases. The comparison of findings from five cases is discussed in sections V. Finally, concluding discussion and future scope is presented in section VI.

II. LITERATURE REVIEW

Review of literature is discussed from the perspective of manufacturing strategy, evolution of manufacturing capability and its assessment. Further, linkage between corporate strategy and manufacturing strategy also has been discussed.

2.1 *Literature review on manufacturing capability and its assessment.*

Research in manufacturing competitiveness has evolved considerably since early conceptual work of Skinner [2]. Author suggested the alignment of manufacturing policies with corporate polices to gain the competitive advantages in the marketplace. Dangayach and Deshmukh [6] argued that even though manufacturing strategy concept presented by Skinner in 1969 but real momentum to the research got after 1990. Competitiveness or competitive advantage is the capability of a manufacturing firm to use its resources in a best possible ways, to achieve the competitive priority, which is a position attained by a business unit and perceived by its customers when compared with its competitors [17]. Leong, K. *et al* [10] presented a process model and content model of manufacturing strategy and identified three causes in a view to improve manufacturing strategy. They are i) Paucity of theory construction, ii) Little empirical research and iii) Insufficient efforts in adopting these concepts. Literature defines the numerous objects of manufacturing strategy and its linkages between them to improve the performance of the firm [1,18, 19]. Conceptual representation of manufacturing linkages and competitive priorities is shown in figure 1.

The level of competitive priorities, solely depend upon the manufacturing capabilities of the production system [3]. Hays and Wheelwright [13] defined competitive priorities as, the way in which a firm chooses to compete in the market place while Hill and Hill [20] defined it as order winners and order qualifiers. Swink and Hegarty [5] proposes that strategic manufacturing (low cost and product differentiation) which requires distinct set of manufacturing capabilities and can be link to the manufacturing outcomes (cost, quality, delivery and time) in order to achieve various dimensions of product differentiations. Sarmiento et al. [21] proposed that manufacturing performance is a cumulative and sequential with quality as foundation, however, Schroeder et al. [22] argues that there is no such consensus about this concept and no empirical testing has been carried out for direct and indirect effects or the sequence of these effects.

Manufacturing strategy consists of a pattern of decisions relating to the sub-systems (decision areas) of manufacturing. Manufacturing capability and its performance depends upon the pattern of decisions taken in the sub-systems of manufacturing [9]. Manufacturing capabilities has to be developed internally which are very difficult to imitate and selecting proper decision area, its decision criteria and its corresponding choices plays a very crucial role [8, 13]. Few research efforts have been reported in the literature in quantifying the manufacturing capability of a firm. Initially, Hayes and Wheelwright [13] defined 35 characteristics (decision criteria) for the four production processes and suggested four stages of the capability (effectiveness) of the manufacturing system. They are namely stage 1: internally neutral, stage 2: externally neutral, stage 3: internally supportive and stage 4: externally supportive. However, a very little empirical research work is done on the strategic manufacturing using Hayes and Wheelwright (1984) framework [23]. Hafeez et al. [24] presented a structured framework using AHP to determine the key capabilities of the firm but does not focused on functional areas like design, manufacturing, purchasing, and marketing of the firm. Hallgren and Olhager [25] suggested a seven stage model for quantification of manufacturing strategy but illustrated the model only with help of example from the literature. Miltenburg [26] carried out the exploratory and descriptive study for factory within factory (FWF) of two multinational companies to examine the linkages between the objects on manufacturing strategy whereas rigorous empirical analysis is left as future work. Yang et al [27] developed hierarchical performance measurement model based on six competitive priorities and 44 criteria but noted that interdependence between these factors is a complex and as focus of future work. Choudhary et al [8] presented framework based on the work of Miltenburg [1] with 54 decision criteria and relevant attributes for seven production processes whereas empirical research is left as a future work. Further, Choudhary et al [14] carried out the exploratory study for job shop and recommended empirical work as future work. Goyal and Grover [28] presented three case studies for measurement of manufacturing effectiveness to prioritize the quality, cost, sustainability, productivity, flexibility, employee, and delivery performance with the help of 35 sub factors using AHP, Graph Theory and Matrix Approach (GTMA). However the influence of manufacturing system on these factors has not been addressed.

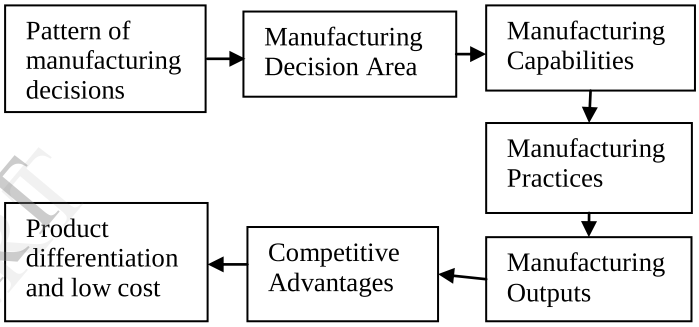

Figure 1: Conceptual model of manufacturing linkages and competitive priorities [1,5]

Literature review indicates that manufacturing capability plays a vital role in deciding the competitiveness of the firm. Researchers have identified certain decision criteria influencing the manufacturing competitiveness. In addition, some attempts are reported to map the patterns of decisions. However, to the best of our knowledge, a combined approach of multi-criteria and case based analysis to generalize the decision pattern in job shop manufacturing environment for competitiveness has not been reported.

III. RESEARCH DESIGN:

This work uses a case study methodology to understand the particular decision choice taken by a manufacturing firm for competitiveness Based on the guidelines given by Yin [29], the research design consists of five components 1) A case study questions 2) Its propositions 3) Units of analysis 4) The logic of linking the data to the propositions 5) The criteria for interpreting the findings.

3.1 A case study questions

Initially, a detailed literature review has been carried out to identify the most widely referred manufacturing sub-systems (decision areas), decisions and decision choices of a job shop. These are summarized in table 1. The hierarchical conceptual model based upon the identified decision areas, decisions and decision choices has been developed. Ideal decision choices for a particular decision have been arrived at based on detailed literature analysis. Jayaram et al. [30] reported that strategy-specific human resource management practices have a significant influence on manufacturing performance namely quality, flexibility, cost and time (Jayaram et al. 1999. For example, HR decision area has seven decision criteria and '*level of skill*' decision criterion has five decision choices [table 1]. The choice of decision criteria is critical for competitiveness. According to Hayes and Wheelwright classical product-process matrix, job shop is recommended for low volume, low standardization, one of a kind product structure where each job is unique and a jumbled flow (process layout) is usually selected as being most effective in meeting product requirements. Therefore, '*highly skilled*' decision choice for the '*level of skill*' decision criterion has been considered as an ideal option for competitiveness and it is rated 10 on the scale 0 to 10 scale [31]. However other decision choices are rated as follows, 7 for mixed skilled, 5 for skilled, 3 for semi skilled and 0 for unskilled. Similar process has been adopted for all the decision choices. For obtaining the relative importance of one attribute over other AHP questionnaire has been applied [table 2]. Current manufacturing capability and likely to be the capability for better competitiveness – referred as ideal capability – has been obtained through multi-criteria approach based on AHP. This has facilitated in understanding the pattern of decision choices in job shop manufacturing.

3.2 Propositions:

Following proposition has been stated to define the scope of the study.

1) Manufacturing capability is mainly driven by infrastructural decision areas than structural and differentiates the products from each dimensions of the competitive priorities [5]
2) Manufacturing capability helps in enhancing the overall level of the manufacturing output, cost,

Table 1 Decision area, decision criteria and decision choices.

Type of decision	*Decision area*	*Decision criteria*	*Decision choices*	*References*
Infrastructural	*HR*	*Level of Skill*	*Highly skilled* *Skilled* *Mixed* *Semi skilled* *Unskilled*	*[1, 8, 13]*
		Employee Participation *Nature of job* *Performance Appraisal* *Training need* *Wage rate* *Work content*	----------------------------- ----------------------------- ----------------------------- -----------------------------	
	OSC *PPC*	----------------------------- ----------------------------- ----------------------------- -----------------------------	----------------------------- ----------------------------- ----------------------------- -----------------------------	
Structural	*PT* *SC* *FY*	----------------------------- ----------------------------- ----------------------------- ----------------------------- ----------------------------- -----------------------------	----------------------------- ----------------------------- ----------------------------- ----------------------------- ----------------------------- -----------------------------	

Table 2 Sample AHP questionnaire for the decision areas

Importance or preference of one Decision area over other										
Decision area	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)	Decision area
HR										OSC
HR										PPC
HR										PT
HR										SC
HR										FY
OSC										PPC
OSC										PT
OSC										SC
OSC										FY
PPC										PT
PPC										SC
PPC										FY
PT										SC
PT										FY
SC										FY

quality, delivery, flexibility, performance and innovation [14]

3) Identification of weak decision areas by comparing the performance of the firm with the ideal system [14].
4) Manufacturing practices/programme/action plan can be suggested based weak decision in order to improve performance of the manufacturing system [1].

The remaining three steps are discussed in detailed in the following three sections. Unit of analysis step is discussed in case study section, whereas logic design to link the data with proposition is dealt in case analysis section. Criteria for interpreting the findings are explained in the conclusion part [29].

IV. CASE STUDY

The case study begins with the case sample selection followed by case protocol development, data collection, data tabulation, case analysis and ends with validity and reliability. These are briefly described below.

4.1. Step 1. Case sample selection

Case sample selection plays a significant role in the final outcome of the study [32]. A single case sample is analogues to a single experiment which represents a significant contribution to knowledge and theory building, whereas multiple case samples are appropriate for the generalization of the research outcome [33, 34]. There is no general consensus about number of case studies (sample size) for generalization of outcome, but there is a general agreement upon four to ten case studies would work well and two tailed design concept was followed while selecting the case samples [32, 33, 14]. Yin [33] and Eisenhardt [32] argues that the selected case sample should satisfy the boundary of our aim in order to connect to the research questionnaire. For this study we have initially contacted seven case companies, after having detailed telephonic conversation with production managers of all companies two cases has been dropped as they failed to qualify the requirements JSPS. After going through the detailed study on the product and process structure five case companies were selected for this study and they were willing to participate. It is observed that similar kind of decisions areas and its required attributes are found in all five cases. Hence it is assumed that the theoretical saturation has been reached and it was conclude that adding more cases in this research does not going to add any significant information to this work. Therefore, the final sample size of five case companies has been decided for the study. Alphabets have been used for Participated case companies to ensure anonymity and confidentiality. Companies are classified in to three sizes that are small, medium, and large based on the number of employees. Company B is a large scale having more than 500 employees; Companies (A, C, and E) are small scale with 50 to 60 employees and company D found to be a medium scale with 200 employees [14].

4. 2 Step 2 Development of case study protocol;

It is an instrument which facilitates general rules and procedure to gather the information in a systematic way. Case study protocol prepared before visiting companies includes information related to product variety and volumes, size of company based on number of employees, annual sales in Indian rupees, order winners, competitive priorities and product experience in years and customization offered in each product. It also included the questionnaire based on the thirty three decision criteria and corresponding decision choices of six decision areas. The protocol consists of the various sources to gather the information like telephonic conversation, website of the company.

4.3 Step 3 Data Collection and Tabulation:

Data was collected through closed ended structured interview using AHP based questionnaire for all thirty three criteria belonging to six decision areas. Two types of information was collected, one relative importance of decision area & decisions and second assessment of decision choice. For computing relative importance, questions were asked to the company personnel to give relative importance of one criterion over other using AHP scale (1 to 9) [35]. For example, if *level of skill* is strongly important than *employee participation* then 5 point has been recorded. Similar approach has been used to obtain the relative importance of six decision area and thirty three decisions. Consistency, if any, beyond 10% was recomputed by informing the decisions maker (manager) to revise the relative importance. The assessment of decision choice rating approach is already explained in section 3.1. Similar rating scale has been used for all thirty three decisions. For this purpose either production head or general manager or assistant general manager were contacted to select the corresponding decision choice suitable for their company. This qualitative information was then converted to quantitative terms using the zero-ten point rating scale. Before visiting physically, the case company has been informed about the objectives of study, approximate time and man hour's requirements. The production system was observed through a visit along with shop supervisor and several issues related production system was discussed. Particularly facility related issues were discussed like, number of days of raw material inventory, how many days the finished product remains ideal without dispatch. On this issue company B manager replies that "we are planning the dispatch of the finished goods on the same day as and when it gets ready for the shipment."Additional information was sought form company website as well as company documents and direct observations. Each plant was visited at least two to three times and each visit lasted for minimum four to five hours. After the visits several phone calls/emails were made to get clarification of information required. The overall manufacturing capability was computed using the formula given below.

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

Where: *S* is the overall manufacturing capability index of the firm; *Wi* is the importance (weight) of the *i*th decision area; *wij* is the relative importance *j*th decision belonging to the *ith* decision area. *Pijk* is the rating value of decision choice of the firm for the *j*th decision belonging to the *ith* decision area.

4. 4 Validity and reliability

Validity and reliability are the two crucial issues in the case study research [33]. Yin, [33] suggested four type of test to find out the quality of case design. These are construct validity, internal validity, external validity and reliability. Construct validity refers to what is to be measure and up to what extent is to be measure. For enhancement of construct validity steps followed include direct observation of production system, data collection from more than one source, getting additional information and clarification through phone calls. Right cause and effects relationship that is conceptual model development refers to internal validity [34]. Pattern matching approach is used for internal validity where data expected though theory is compared with the pattern of observed characteristics. The decision area and criteria which observed in the case company matches with literature available which satisfy the internal validity.

External validity offers generalization of the study findings. For this, sample of five cases has been studied to address external validity [29]. Design and development of case protocol and data collection from multiple sources tackled the issue of reliability [33].

V. CASE ANALYSIS

Case analysis for all five cases followed by the cross-case analysis is explained in this section. The performances of each decision criterion along with their ideal values obtained from the literature for all cases are discussed in this section.

5.1 Within case analysis

Within case analysis typically involves detailed description about each case studied during the research [33], it is depicted in table 3.

5.2 Cross-case analysis

The cross case analysis has been carried out to focus on commonalities and differences of the findings across all the five cases by selecting the decision areas and their corresponding criteria [32, 36,14]. Figure 2 represents performance comparison of decision areas of all firms with the corresponding ideal cases, whereas figure 3 shows the gap analysis of decision areas. The purpose of this analysis is to validate the decision areas, criteria presented in the literature and also to find commonalities and differences between them. [32].

5.2.1 Human resources

There are total seven decision criteria in the HR decision area. Our study observed that case B is found with least gap of 3.9% out of total gap of 15.26% and case A found with maximum gap of 45.26% out of total gap of 34.25% in HR decision area when their performances compared with ideal system of the same environment. More the gap lesser is the capability which is found for case A and B, whereas cases D and E found with same capability but the gap for D is 23.62% and for E 7.24%. Even though the gap for D found more but *employee participation* decision choice matches with ideal which is highly desirable for JSPS, but that is not found for case E. Case C found with mismatch of three criteria but the *skill level* criteria matches with ideal case and hence its capability found more than the cases D and E. Only the cases B and E are paying high wages to their workers, on this matter owner of the company E replies that "we are employing skilled level worker at the entry level and by giving in house training we are raising their skill as well as wages". The case company A, C, and D are paying moderate wages. The production manager of case A responses that "high wages is not affordable for us since we have to maintain level of cost and quality of products in comparison with our competitor."

Table–3: Background of the five case companies

	Case A	*Case B*	*Case C*	*Case D*	*Case E*
Products	*Reactors, Heat exchangers, filters and many mores*	*All types of boilers, super heaters, heat exchangers*	*Cold rolling mills rolls*	*Agitators, tooth paste mixers, pressure vessel, and storage tanks*	*Various types of machine components, tooling.*
Company size (Number of employees)	*60*	*220 plant (Total 7000)*	*50*	*200*	*45*
Sales in INR	*170millions*	*2500 millions*	*60millions*	*400 millions*	*40 millions*
Order winners	*Quality, flexibility and delivery.*	*Quality, reliability, innovation*	*Quality and cost*	*Quality, cost and delivery speed*	*Flexibility, delivery and quality*
Individual product size	*1-25*	*1-35*	*1-50*	*1 to N number*	*1 to 3000*
End product experience	*16 years*	*52 years*	*27 years*	*25years*	*14 years*
Customization offered in each product	*Customized*	*Highly customized*	*Customized*	*Highly Customized*	*Highly customized*

5.2.2 Organization structure and control:

JSPS is the most dynamic production system in comparison with other production system therefore flat organization structure and decentralized decision making is preferred. Case company C, D, and E found flat organization structure whereas Case A follows the hierarchical structure and case B follows mixed kind organization structure. The Assistant manager production of the shop (PC1) of case B commented that "since ours is a very big organization we follow mixed kind of organization structure. Assistant general manager of our shop is having a full authority of taking the final decision about manufacturing related activity of our shop". Case B, C and E follows decentralize decision making policy whereas case A and D follows centralize decision making policy. Worker is responsible for the quality of the job in case JSPS [13,14] which is observed in case of company B only. Quality responsibility of the job for other cases varies from worker with supervisor towards the team and then quality control and process control specialist. Line staff plays a significant role for JSPS since innovation is the most important manufacturing output. Case B gives very high importance to the line staff in comparison to others which was giving moderate importance. Here also least gap of 1.68% found for case B and maximum gap 12.99% found for E and 5.56% for A.

5.2.3 Production planning and control:

To responds to fluctuating demands JSPS follows chase strategy [14,1], in our analysis except for case A satisfies this finding of the literature. JSPS uses customer order as planning inputs all cases under study support this finding of the literature. The finished goods inventory is very low since this manufacturing environment based on make to order policy our analysis for all cases support this finding. The raw material inventory is generally low when variety is important than volume, we found that low level of inventory for cases A, B, and C and medium level for D and E. Because of less automation and decoupling of the various processes Work in Process Inventory (WIP) is high for JSPS, company B and C found with high WIP and A, D and E maintain medium level of WIP. Since this is a variety driven production system each product requires different set up for its processing and very high production information which impact on large uncertainty of scheduling. In all five cases it was found that there is rare uncertainty of scheduling. The assistant manager – production of case B replies that "our company is having planning software which is based on theory of constraint which select the priority of processing depends upon delivery plan of the final product". For other cases company personnel told that "since we are in same business from past so many years we can take care of scheduling of the job and also new product order as and when it receives. Production information requires for cases A, B, C, D is very high but for E is high. To accommodate a large variations in product specification set up time require is more that the run time. In our cases A, B, C has requires more set up time than case D and E, since case B has a policy of processing similar kinds of jobs on same setup which reduces the setup time but increases the backlog getting the benefits of economies of scale. Length of planning horizon for JSPS is large [, 14] which we found for cases B and D whereas cases A, C, and E has medium length of horizon. Author Safizadeh [37] further argues that shorter length of planning horizon and zero backlogs enhance the level of delivery speed and reliability. In overall our study found that minimum mismatch that is only two decision criteria for case B and maximum mismatch of seven and six criteria out of total ten found for case E and A respectively which is affecting positively on overall capability.

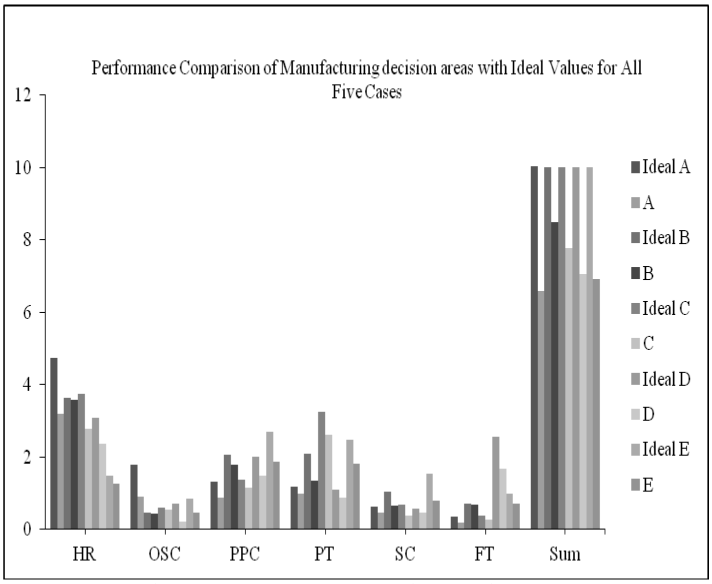

Figure 2Performance Comparison of Manufacturing decision areas with Ideal Values for All Five Cases.

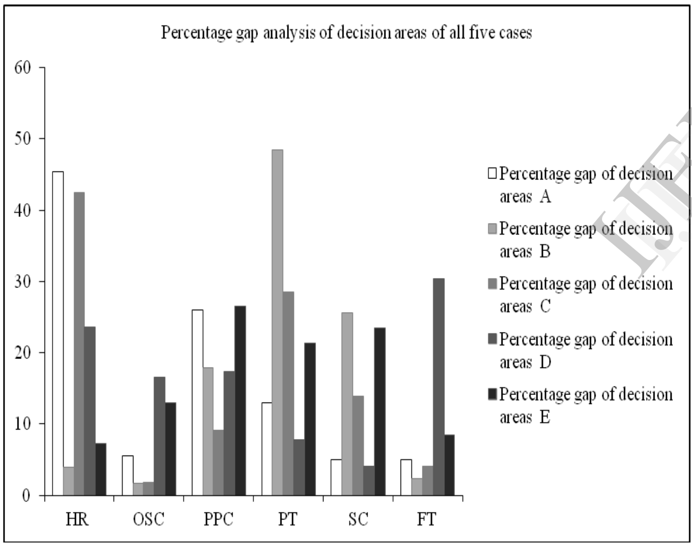

Figure 3 Percentage gap analysis of decision areas of all five cases

5.2.4 Process technology:

Flow of product is not fixed for large variety, low volume manufacturing environment and general purpose machinery with process layout is appropriate to handle this kind of situation [1, 14]. All cases of our study use a process layout. Since the JSPS produces ~~100%~~ customized products extensive use of AMT in product design is must [37]. This study observe that case A, C and D uses little level AMT for product design and follows traditional approach for manufacturing and case B and D uses medium level of AMT. Manager of the case B was very much agrees with use of AMT to the extensive level for product design. Use of automation for material handling in case JSPS is difficult as it produces large variety with process layout. Case A and C have a very little use of automation and follows traditional approach in manufacturing and material handling. Cases B, D, and E uses medium level automation to design the components with help of CAD packages and CNC for manufacturing. Thus automation is mainly limited to processes like loading, unloading, activities and to some extent in product and process design. Coupling of two processes is not preferred for process layout kind of manufacturing environment, our finding shows that A and B has no integration of processes and cases C and D has medium integration followed by E which is having loose integration. Type of tooling depend upon the volume of the product and hence process technology, in our study all case uses low volume tooling. For process technology area company B found with maximum gap of 48.95% which is negatively affecting the overall capability and D found with least gap of 7.8% helps in enhancing the level of overall capability.

5.2.5 Sourcing:

This decision area includes decisions like number of suppliers, relationship with suppliers, control over the suppliers, degree of vertical integration and material requirement prediction. Generally traditional JSPS have large suppliers with less control on supplier because of irregular order, whereas world class follows few suppliers with better control [13, 38]. Our observations shows that only case D have large number of suppliers and case A and B have many suppliers and C and E found with few numbers of suppliers. Since company D is having large number of suppliers, control over them is very high, but rest other cases have moderate control over the suppliers thus contradictory with the literature. Relationship with suppliers has a positive impact on flexibility, delivery speed and reliability [39,14]. We observed that Case B maintain long term (strategic) and other cases maintains tactical (medium range) relationship with suppliers [40]. JSPS prefers very low degree of vertical integration which is observed for case B, while for other cases follows medium kind of vertical integration and Case C found with high vertical integration. Fluctuations in demands and variety in products calls for a difficulties in material requirement predictions. Our observation shows that for case A and E found to be somewhat predictable in material requirements because of repetitions of parts at regular intervals. Case B manager replies that "since we are in the same business from past 4 to 5 decades and getting repeat orders with changes in some parameters, material requirement is highly predictable for us." Case D and A performs well with the least gap of 4.13% and 5% whereas D found with maximum gap of 25.59%

5.2.6 Facility:

Facility decision area comprises of two decision namely type of facility and size of facility. Size of facility represents size of the company which top management decides based upon the availability of raw material, market and product demands [14]. JSPS requires a small size facility, this study observe this for cases A, C, E and D, with medium size of facility, large size facility for case B. For accommodating large variety of product general purpose facility with less automation is preferred [1] which is found in company C and D. Least gap found for case B, C and A which is equal to 2.33%, 4.1% and 5.01% respectively, followed by 8.47% for E and maximum gap of 30.39% observes in case D.

VI. DISCUSSION AND CONCLUSIONS

The present work contains the case based approach to evaluate the manufacturing capability of five cases using 'AHP' a multi criteria decision making method. For this study a conceptual model with six decision areas, thirty three decision criteria have been developed. The highest capability of 8.474 found for case B and lowest of 6.575 observed for case A using scale of 0 to 10 (figure 4). The lowest and highest value of manufacturing capability index reveals that the theoretical sampling of cases satisfies the concept of two tail design [29, 41]. Literature noted that these capabilities derive less from structural decision areas and more from infrastructural decision areas supports the first proposition [5, 13]. Further this study compared the performance of each decision criteria with the ideal performance from the same manufacturing environment followed by the gap analysis. Higher value of capability reflects fewer mismatches in decision criteria of company when it compares with ideal system, resulting the enhancement the level of manufacturing outputs [1]. In overall out of total thirty three decision criteria, case B shows very less mismatch of 11 decision criteria, out of that five from infrastructural issues (training needs, organization structure, scheduling, set up to run time, etc) and six from structural issues (use of AMT, degree of automation, number of suppliers etc.) which has positively affecting the overall manufacturing capability of case B in enhancing the level of outputs and thus supports the second proposition. It can also be concluded that overall performance of case B found to be moving towards the world class manufacturing company in a sector of make to order [38]. Maximum mismatch of 21 decision criteria found for case 'A' affecting the manufacturing capability negatively to the value of 6.65. For the cases C and D we have observed same number of mismatch of decision criteria that is 17, but number of mismatch of criteria from infrastructural issues was less for C (9) than D (12) affecting positively on the overall capability supports the literature. Case C is having 7.76 and cased D is found 7.05 value of manufacturing capability out of 10. To support this findings we have further analyzed the gap in the individual decision area and it found that case C performed well for four decision area that are OSC, PPC, PT and FT when it was compared with case D. From above analysis it is clear that the present model developed and tested with case study supports most of the findings of literature, whereas it can be modify based on the outcome of this work to make this model robust and generalizable. About the process technology decision area even though case B shown maximum mismatch of 48.49% which clearly shows that PT mismatch does not affects much on capability and supporting the literature findings [5, 13,]. For sourcing decision area least gap of 4.13% found for the case D but capability value is 7.05 and maximum gap observed for the case B and 25.85% and capability value is 8.474 this results does not follow any kind of pattern noted in the literature therefore this outcome suggest some modification in the presents model. About facility decision areas again case B after HR decision area found least gap of 2.33% followed by C = 4.15%, A= 5.015%, E= 8.47% and maximum gap of 30.39% for case D, this result is found little bit contradictory with the literature findings. In this way the detailed analysis has been carried out to compares each and every decision for all cases to find weak decision for further improvements which supports the third proposition.

The manufacturing capability index computed facilitates the manager for benchmarking and also it gives guidelines for improving the identified weak decision areas. The findings of this work cannot be generalized to large extent since it is based on only five case studies. It should be empirically tested for large population of JSPS in order to strengthen the outcome of this work. This work can be extended to map the relationship between the manufacturing capability and competitive priorities (cost, quality, delivery, flexibility, performance, and innovation) in order to gain competitive advantage in the market place. This work has considered only hierarchical relationship between the decision areas its corresponding criteria and their relevant attributes whereas Analytical Network Process (ANP) or Graph Theory and Matrix Approach (GTMA) techniques can be used to study the interrelationship between theses parameters. The limitation of this research is that, only manufacturing capability index has been calculated and suggested weak decision area whereas the implementation of corresponding manufacturing practices/action programme/policies to improve these weak decision area is left as a future work which supports the fourth proposition. Multiple investigators (team of researchers) build the confidence in the findings and increases strengthening of the findings, since multiple investigators have different perspectives [31]. The conceptual model developed in this study on the basis of general literature of Make to Order sector (MTO) whereas future researchers can modify this model using

the concept of World Class Manufacturing (WCM) by considering the outcome of this analysis [38].

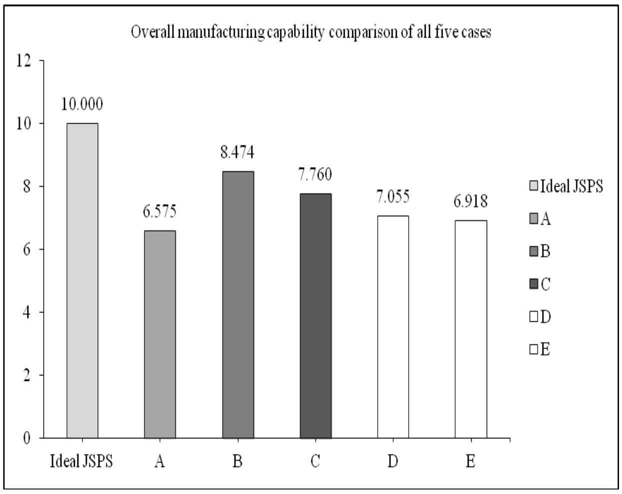

Figure 4: Overall manufacturing capability comparison of all five cases

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