The International Journal of Engineering and Science (IJES)
|| Volume || 13 || Issue || 7 || Pages || PP 85-90 || 2024 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Competencies on advancement in New Manufacturing-An Empirical Study

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Abstract: To gain insights and understand the correlation among the manufacturing capabilities, different manufacturing capability development theories are investigated In this research paper we will investigate the capability development paradigm of new age manufacturing competence. This paper attempts to explain the unsettled controversy on capability development paradigm. Well planned questionnaire was used to record data from manufacturing organizations. Random samples are taken from Indian manufacturing industries to test the propositions of capability development.

Keywords: competitive priority, manufacturing capability, process choice, tradeoffs, cumulative and integrative

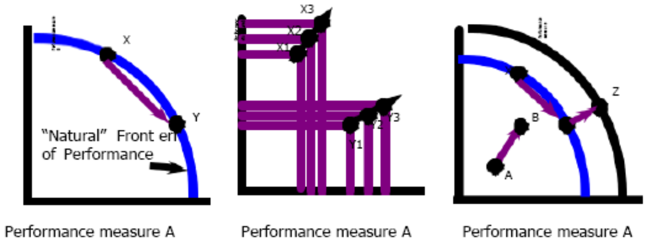
I. Introduction

In the era of cut throat competition, manufacturing companies are facing severe pressure and it is imperative that manufacturing provide high competence. In order to achieve high degree of competitive success in market, manufacturing requires greater ability in dimensions of cost, quality, delivery, flexibility and innovativeness. Competitive priorities define the goals of manufacturing (Leong et al., 1990) in the above dimensions while a closely associated term ―manufacturing capabilities,‖ refers to performance of production system in the same dimensions. Thus, ―competitive priority‖ refers to the importance while manufacturing capability refers to the performance in the dimensions of cost, quality, delivery, flexibility, and innovation.

Based on the demand characteristics of the market they serve and economics of production, production functions organize and deploy their resources differently. A common classification scheme used for production systems, called ―process choice,‖ entails four categories: job shop, batch, line flow, and continuous flow (Hayes and Wheelwright 1979). It is widely quoted in literature that the manufacturing competencies that can be attained by a production system to an extent depend upon the process choice. For example, job shops are used to produce low volume customized product employing high flexibility but at a high unit cost whereas continuous flow shops produce high volume standardized product employing less flexibility but yielding a low unit cost. Safizadeh et al. (2000) found that even within a given process choice the manufacturing capability of plants could vary as some plants employ most improved processes and technologies than others.

Manufacturing capability development: How are the competencies in manufacturing developed to provide higher level of manufacturing capability in the dimensions of cost, quality, delivery speed, delivery reliability, flexibility and innovation, leads to alternate manufacturing capability.

development paths. Three perspectives of capability development: the tradeoff, cumulative, and integrative models (see Fig. 1) are reported in literature as discussed below. Skinner (1969) proposed the tradeoff model according to which improvement of one of the generic capabilities is possible only at the expense of the others. For example, a company which opts for flexibility of its production, if successful, would improve the flexibility but its cost efficiency or dependability of its deliveries might fall behind industry standards. This gives an idea of positioning as manufacturing being technologically constrained cannot provide all things to all people (from point X to Y in Fig. 1a)(Skinner 1969). Certain tradeoffs in capabilities are implicit in process choice itself. However, the set of tradeoffs can change or even disappear from one process choice to another (Safizadeh et al., 2000). Cumulative view of capability development claims that tradeoffs are not necessary as advanced manufacturing technologies can simultaneously improve capabilities in multiple dimensions (e.g., from point X1 to X2 in Fig. 1b) (Schonberger, 1986; Ferdows and De Meyer, 1990; Noble, 1995). The integrative perspective seeks to reconcile differences between tradeoff and cumulative models (Hayes and Pisano, 1996). The companies operating at industry standard (the economists refer it as being close to ―the efficient frontier‖ of its resource utilization) can reposition in short term (see, path XY in Fig. 1c). However, in long run trade-offs can be overcome by technological improvements (from XY to Z in Fig. 1).



(a)Trade – off model (b) Cumulative model
(c)Integrative model

Figure 1: Three schools of trade-off thoughts

On critical examination of the available literature, several contradictory and non-conclusive results exist in literature for understanding trade-off, cumulative and integrative approaches of capability developments. Here we seek to test and contribute to the debate on these paradigms.

An attempt is made to understand the correlation among the competitive priorities and gain insights into the manufacturing capability development path (e.g., trade off, cumulative or integrative) through samples from Indian manufacturing companies. It seeks answers for some specific questions, such as: Do plants with different process choices face different tradeoffs between their manufacturing capabilities? Are these tradeoffs different when all the plants are considered together? Are tradeoffs likely to occur only between certain specific pairs of manufacturing capabilities (e.g., cost and flexibility) and not with other manufacturing capabilities Specific propositions keeping the above objectives in mind are developed in section 3 and validated in section 4.The remainder of this paper has four sections. Section 2 reviews the relevant literature. Section 3 describes the research design discussing the survey instrument, sample composition, and the constructs used in the study. Section 4 presents data analysis, findings and discussion. Section 5 provides summary, lists the study's limitations and offers some concluding remarks.

II. Literature Review

Pertinent literature related to manufacturing capability development path such as tradeoff, cumulative and integrative perspective is discussed next.

Skinner (1969) and his disciples had argued that different production systems exhibit different operating characteristics: some were good at low cost, some at fast delivery, some at high flexibility and some at high quality, etc. One common interpretation of Skinner's argument is that manufacturing firms cannot perform well on all capabilities, and that superior performance in some capabilities can be gained only at the expense of others (Slack and Lewis, 2008). Therefore, companies must prioritize their competitive objectives and devote resources to improve performance in the main objectives Boyer and Lewis (2002). In their classification of production systems via the product-process matrix, Hayes and Wheelwright (1979) also observed clear tradeoffs among manufacturing capabilities in selecting a process choice. The process choice for a production system, or for a major process within it, is not a once-and-for-all decision. Process change may be viewed as shifting from one process choice to another or making improvements in the same process choice for better manufacturing capabilities (Safizadeh et al., 2000).

Safizadeh et al., (2000) examined the aspects of tradeoffs and found evidence in support for the theory and related it to process choice. A series of studies based on survey analyzed correlations between competitive priorities in manufacturing to investigate which trade-offs were real (Boyer and Lewis, 2002).

Studies in the 1980s and early 1990s challenged the traditional approach to trade-offs observing manufacturing companies performing better than competitors in different areas simultaneously (Ferdows and De Meyer, 1990; Noble, 1995; Hayes and Pisano, 1996). The World Class Manufacturing'' school suggested trade-off as a myth—the application of Just-In-Time and Total Quality Management principles allowed manufacturers to be good in all areas of performance such as flexibility, quality, delivery, and cost (Schonberger, 1986). Advocates of the cumulative model, however, claim that tradeoffs are neither desirable nor necessary for two reasons. First, global competition has intensified the pressure on plants to improve along all four dimensions. ―World Class

Manufacturer‖ set the standard developing capabilities that reinforce each other (Boyer and Lewis, 2002). Second, Advanced Manufacturing Technology (AMT), Flexible Manufacturing System (FMS), Computer Integrated Manufacturing (CIM) and other programmable automation help plants to develop multiple capabilities simultaneously (see Fig 1b).

Constant improvement in manufacturing is necessary to achieve superior manufacturing capability. Few companies have competed successfully over an extended period of time, and staying ahead of rivals gets harder every day. The most obvious reason for that is rapid diffusion of new technology and best practices. Operational improvements shifts the productivity frontier outwards (see Fig. 1c), effectively raising the bar for everyone i.e. manufacturing trade-offs are dynamic, and can be repositioned or enhanced through managerial actions Hayes and Pisano (1996).

Thus it is evident that several contradictory and non-conclusive results exist in literature for understanding trade-off, cumulative and integrative approaches of capability developments. Also, very few empirical studies have been reported in the literature that promote, negate or integrate the tradeoff model (Boyer and Lewis, 2002).

III. Research Design

The use of field based empirical methodologies in manufacturing strategy area has been steadily increasing over the past few years. One of the most prominent among these is the survey research methodology which has been used to capture data from manufacturing organizations. This study also employs survey research methodology to test capability development paradigm of manufacturing competence. Our unit of analysis is dominant process and product at individual plant level. A statistical software SPSS is used in this paper to analyze data using correlation and regression analysis.

The objective is to empirically study the unsettled capability development paradigms with new set of data. Following propositions are accordingly formulated:

Proposition 1. Do plants with different process choices face different tradeoffs between their manufacturing capabilities? Are these tradeoffs different when all the plants are considered together? *Proposition 2*. Are tradeoffs likely to occur only between certain specific pairs of manufacturing capabilities (e.g., cost and flexibility) and not with other manufacturing capabilities? Various constructs along with measuring scales to test our research propositions are discussed next.

Competitive priorities define the goals of manufacturing (Leong et al., 1990) to meet the needs of the market in the dimensions such as cost, quality, delivery speed, delivery reliability, flexibility and innovation by specifying the importance attached to these dimensions while manufacturing capability define the performance achieved in the above dimensions. Constructs used to measure competitive priorities and manufacturing capabilities in this research are similar to that of Leong et al. (1990) and are given in Appendix I. Importance attached to the competitive priorities for major products are rated on five point Likert scale (1. Not Important; 2. Somewhat Important; 3. Quite Important; 4. Very Important and 5. Extremely Important). For measuring manufacturing capability, performance with respect to competitors is rated on five point Likert scale (1. Significantly Lower; 2. Somewhat Lower; 3. About the same; 4. Somewhat Higher and 5. Significantly Higher). Except for cost, higher score means better performance. The question for cost was worded such that higher score means worse performance (higher cost).This question was reverse coded to make its score consistent with the other questions. Also the responses for two dimensions of delivery and flexibility were averaged. For analysis of data, five dimensions of capabilities i.e. cost, quality, delivery, flexibility and innovation, were considered.

Correlation coefficients between competitive priorities (such as cost, quality, etc.) can help understand the path of competency development of various organizations. Generally, a positive correlation between two competitive priorities will mean parallel (e.g., cumulative) development of the two capabilities and negative correlation implies that one capability is developed at the cost of other employing a trade-off between the two.

3.1 Data collection

Personally administered structured interview (using questionnaire) method was used to collect primary data from the managers of manufacturing companies in India. Based on convenience of the researcher and the willingness of the managers to participate, case companies were selected for this exercise. Personal contact and contact through friends helped in identifying these companies. The structured questionnaire developed (Appendix I) was administered to managers in the plant who help develop manufacturing strategy in their daily work. Pilot testing of the survey with a small sample of respondents changed the wording of few questions. Managers were also asked to provide information about their organization for the research instrument and were ensured about the secrecy and anonymity of their responses. They were requested to mail the completed questionnaire to the researcher. A total of 53 participants from 47 manufacturing companies completed the questionnaire. Table 1 provides the profile of case companies covering diverse fields like automobile, power, pharmaceutical, equipments and machineries, railway coach and consumer products. Also the companies are a mix of small scale, medium and large scale with broad range of turnovers.

Table 1: Profile of the companies from where data was collected

Statistics of respondent companies	
Company's Products	Commercial vehicle (3) ; Farm tractor(1) Power (3) ; Railway coach (1); Equipment and machines (22); Pharmaceutical (3); Steel(2); Oil(1); Cement(1),Consumer products (10)
Annual turn over (in millions of Indian Rupees)	< 1000 (13); 1000 - 10000 (19); > 10000 (15) ;
Number of employees	< 500 (23); 500 - 5000 (16); > 5000 (8)
Type of production system used	Job shop (7); Batch shop (15); Line shop (13) ; Continuous shop(12)

IV. Analysis, findings and discussion

In this section, we analyzed the data and test the propositions formulated in section 3. Statistical method of correlation analysis was employed to analyze the data to examine propositions.

Correlation coefficients between all pairs of capabilities were computed to estimate the tradeoffs or no tradeoffs. If the correlation between a pair of capabilities is positive, it means parallel development of the two capabilities (cumulative development) and negative correlation implies that one capability is developed at the cost of the other (trade off). Such relationships can be determined either by considering importance given to them in the market or by performance with respect to competitor. Boyer and Lewis (2002) considered competitive priorities using importance score for finding the relationship between them to study trade-offs. However, when they used data with absolute value of importance on a scale of 1 to 7 it did not reveal tradeoffs. They suggested transformation of competitive priority measures by computing competitive priority (i.e. cost, quality, etc.) minus the respondent‘s average for all the constructs and then divide this difference by the standard deviation for all the constructs for that company which clearly showed tradeoff between cost and flexibility. We conducted similar analysis using our data and the result is given in Table 2. It shows the correlations between competitive priorities for the data of all the companies. Tradeoff is not significant and there is positive correlation (+0.322) between quality and innovation when data was not normalized. But when normalized data are considered, tradeoffs are observed between cost and quality, cost and innovation, quality and delivery, quality and flexibility, delivery and innovation and flexibility and innovation which supports Boyer and Lewis (2002) that normalized data should be used to unravel the trade offs of competitive priorities.

Table 2: Correlations between competitive priorities (all plants)

Scale used for —importancel	*Correlations between competitive priority dimensions						
	Cost & Quality	Cost & Innovation	Quality & Delivery	Quality & flexibility	Quality & Innovation	Delivery & Innovation	Flexibility & Innovation
Data not normalised					0.322		
Normalised data	-0.309	-0.472	-0.332	-0.417		-0.411	-0.300

*Correlation is significant at the 0.05 level

Safizadeh et al. (2000) considered the correlation between the performance scores with respect to competitor rather than importance to understand capability development. Next we follow the approach of Safizadeh et al. (2000) since it provides rating with respect to competitors which does not require normalization of data unlike importance. Table 3 shows the correlation coefficients between competitive priorities for the entire sample as well as for each process choice category such as job, batch, line, and continuous.

Table 3: Correlations between manufacturing capabilities

	*Correlations between manufacturing capabilities dimensions						
Manufacturing capabilities	Cost & Innovation	Quality & Delivery	Quality & Flexibility	Quality & Innovation	Delivery & Flexibility	Delivery & Innovation	Flexibility& innovation
A. All plants		0.494		0.388	0.358	0.406	0.330
B.Process choice:							
Job shop		0.833	0.804	0.786			
Batch							
Line		0.573			0.755		0.705
Continuous	0.587	0.648					

*Correlation is significant at the 0.05 level

Part A of Table 3 shows parallel development of quality and delivery; quality and innovation; delivery and flexibility; delivery and innovation and flexibility and innovation. This finding endorses the cumulative model of tradeoff in which plants develop multiple capabilities simultaneously. However, our results do not show any tradeoffs between the pairings of manufacturing capabilities.

Part B of Table 3 suggests that different set of tradeoffs emerges when the process choice is fixed. It is also observed that in job shop, quality and delivery, quality and flexibility, and quality and innovation exhibit positive correlation. In batch shop, no significant correlation exists, which is quite in contrast to Safizadeh et al. (2000) who found largest number of significant correlations in batch shop. Line shop shows parallel development of quality and delivery, delivery and flexibility, and flexibility and innovation. Cost and innovation and quality and delivery go hand in hand in continuous shop.

Our results in Table 3 do not support proposition 2, as we could not find tradeoff between certain specific pair of capabilities. Instead, we found concurrent development of manufacturing capabilities.

V. Summary and Conclusions

Review of literature indicated that there is relative paucity of case and field research in the area of manufacturing strategy.

This paper conducted a survey research to address the following research gaps. To gain insights and understand the correlation among the manufacturing capabilities, different manufacturing capability development theories are investigated. Based on the above objectives, propositions were formulated and tested by analyzing the data. The following findings were observed.

We observed that capability developments for plants with various process choices are different from the case of considering all plants together. We noticed concurrent development of several pair of capabilities and moreover this gets changed when process choice is in place. We could not find tradeoffs between cost and flexibility or any other pair of capabilities. No significant correlation was found in batch shop, which is quite opposite to that of Safizadeh et al. (2000) who found largest number of significant correlations in batch shop.

The results investigating the paradigm from the analysis of a sample that could be gathered in this research are encouraging as it supports the propositions. This exploratory study is based on a small sample of manufacturing companies with diversity and hence it may not be representative of all industry sectors. However, future studies with larger data can corroborate the findings.

Acknowledgement

The authors are grateful to the respondents from various organizations for providing data for the questionnaires used in this research.

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Appendix I: Benchmarking Manufacturing Performance

Consider each ―Manufacturing Capability Dimensions (*meanings are provided in the table given in the bottom of this page)‖ and rate these products on **Importance** that attach to it in selling the products and **Performance** of your product relative to your significant competitors.

1.IMPORTANCE OF COMPETITIVE PRIORITIES: For each dimension (i.e., Row), tick (√) in appropriate boxes.

Manufacturing Capability Dimension	IMPORTANCE of your major product(s) in the market place.				
	1. Not Important	2. Somewhat Important	3. Quite Important	4. Very Important	5. Extremely Important
1.**Cost**					
2. **Quality**					
3. **Delivery performance**					
A) Dependability of delivery					
B) Speed of delivery					
4. **Flexibility**					
A)Product mix					
B)Production volume					
5 .**Innovativeness**					

2. PERFORMANCE OF COMPETITIVE PRIORITIES: For each dimension (i.e., Row), tick (√) in appropriate boxes.

Manufacturing Capability Dimension	PERFORMANCE [as compared to your major competitor(s)].				
	1. Significantly Lower	2. Somewhat Lower	3. About the Same	4. Somewhat Higher	5. Significantly Higher
1.**Cost**					
2. **Quality**					
3. **Delivery performance**					
3A) Dependability of delivery					
3B) Speed of delivery					
4. **Flexibility**					
4A)Product mix					
4B)Production volume					
5 .**Innovativeness**					

***Table: Dimensions of Manufacturing Capabilities [or Competitive Priorities] and their meaning**

Dimension	Meaning
1. Cost	Production and distribution of the product at low cost.
2. Quality	Manufacture of products with high quality and performance standards.
3. Delivery performance	
• **Dependability of delivery**	Meet delivery schedules or promises.
• **Speed of delivery**	React quickly to customer orders.
4. Flexibility	
• **Product mix**	React quickly to changes in types of products manufactured.
• **Volume**	React quickly to volume changes of a given product mix.
5. Innovativeness	Introduction of new products and processes.