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Manufacturing Flexibility and Firm Performance: Literature Review

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Abstract

Manufacturing flexibility has been considered both as a reactive and proactive tool for dealing with environmental uncertainty. Flexibility allows operations to maintain and improve performance in spite of variety, uncertainty, and ignorance. A number of empirical studies exist where researchers have attempted to correlate flexibility attributes with the firm performance. Although several studies have been done to find different contexts in which investment in flexibility may make economic sense, there is a clear need of understanding the direct and indirect linkages of flexibility with firm performance. So, the literature was assessed on the ground of factors that affects the relationship between manufacturing flexibility and firm's performance. This review extracts relevant contents like "strategy", "technology", "uncertainty", "organizational attributes", "innovation" and "product types" that may influence the successful implementation of manufacturing flexibility in an organization.

Keywords: *Manufacturing Flexibility/Firm Performance/Uncertainty/Strategy/Technology*

Introduction

Given the challenges of ever increasing competitive environment, it is self evident that successful firms have to constantly adapt to changing environmental conditions along with performing better than their competitors (Handfield and Nichols, 1999;Boyle *et al.*,2008). The development of low cost, high quality products does not guarantee success of a firm in isolation (Upton, 1995). A firm should have enough manufacturing flexibility to meet the market needs in a timely, cost-effective, and efficient manner (Gupta, 2003; Chang *et al.*, 2001). Flexibility in manufacturing system is required mainly due to decreasing time to market, shorter life cycle and mass customization (Kara and Kayis, 2004). Slack (1991) suggested that the need for manufacturing flexibility arises mainly due to four sources, namely, *variety* regarding demand of various range of products, short-term uncertainty arising due to uncertainty in maintenance performance, long term uncertainty regarding emerging technologies and market conditions, and ignorance about the appropriate strategic direction of manufacturing functions due to lack of knowledge about the overall firm strategy. Thus, the challenges of competitive environment require the adoption of manufacturing flexibility for the firms as a strategic option for achieving better business performance. Flexibility is required in order to handle uncertainties and variations in both the internal and external environment (Kara and Kayis, 2004). It can be strategically used for defensive as well as offensive purposes (Swamidass, 1988). As an example, during Honda- Yamaha war

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in early '1980' Honda launched 81(new) models within eighteen months and discontinued 32 models for a total of 113 changes in the product lines for sustaining its number one position in motorcycle industry (Abegglcn and Stalk,1985). Thus, Flexibility has been highlighted by both researchers and managers as a critical component of the manufacturing strategy.

Purpose of the Study

The purpose of this study was to understand the concept of manufacturing flexibility and various factors associated with it that affects the relationship between manufacturing flexibility and firm's performance. The present study focuses on understanding of direct and indirect linkages of flexibility with firm performance.

Methodology

The exploratory study makes an effort to analyze the literature on manufacturing flexibility from 1990 to 2011. The keywords used to search the paper were manufacturing flexibility, manufacturing strategy, business strategy, uncertainty, manufacturing technology, organizational attributes for flexible production, contingency theory and firm performance. The sensitive search strategy was adopted. As per this strategy, all the possible ways that an author might describe keywords and phrases were thought of to collect and document the relevant literature. Published literature and reference sections of published work were used as a starting point for the search. Structured literature review was carried out by using "Science Direct", "EBESCO" and "PROQUEST" for all the available years and research institute libraries. The studies published in English only were included in the literature review. High frequency citation articles were given preference in selection of research references. Both, qualitative and quantitative studies were included. The synoptic overview of the research studies is presented in Table 1.

Table 1: Synoptic Overview of Research Studies Till Date

Conceptual Papers	Survey Papers	Other relevant research
Swamidass(1988), Gerwin(1993),Upton(1995;1997),Koste and Malhotra (1999), Vokurka andO'Leary-Kelly (2000), Beach *et al.* (2000), Narain *et al.*(2000),Kara and Kayis(2004), Schmenner and Tatikonda (2005), Narain *et al.* (2005), Slack(2005), Oke (2005), Voss (2005), Sawhney(2006), Boyle(2006),Stanev *et al.* (2008),Lucas and Kirillova (2011)	Swamidass and Newell (1987), Dixon(1992),, Parthasarthy and Sethi (1993), Ettlie and Penner -Hahn(1994),Miller and Roth (1994), Gupta and Somer (1996), Suarez *et al.* (1996), Boyer *et al.* (1997), Vickery *et al.* (1997),Berry and Cooper (1999) , Bardi *et al* . (2000), Das(2001), Chang *et al* . (2002), Anand and Ward(2004), Dreyer and Grønhau (2004),Koste *et al* . (2004), Swink et. al. (2005) , Llore´ns *et al* . (2005) ,Chang *et al* .(2005), Ling-yee and Ogunmokun(2007), Avittathur and Swamidass (2007),Larso *et al* . (2008),Hallgren and Olhager (2009), ,Boyle and Scherrer -Rathje(2009)Chi *et al* . (2009), Fantazy *et al* .(2009) Camiso´n and Lo´pez (2010), Buganza *et al.* (2010), Patel (2011),	Olhager andWest(2002), Narasimhan *et al.*(2004), Oke(2005), Hutchison and Das (2007), Baykasog˘lu and O¨ zbakır (2008), Wilson and Platts(2010), Esturilho and Estorilio (2010),Chang(2011),

Manufacturing Flexibility

Definition

Over a period, many researchers have defined the term "manufacturing flexibility". Early work of Skinner (1969) recognized manufacturing flexibility as one of the manufacturing objectives including costs, quality, delivery, dependability and delivery speed. Further, Wheelwright (1978) proposed efficiency, dependability, quality and flexibility as the most general criteria for evaluating manufacturing strategy. Later, Hayes and Wheelwright (1984) described four basic competitive priorities of a manufacturing firms are cost, quality, dependability and flexibility. Further, Leong *et al*. (1990) argued that the most critical criteria for measuring manufacturing strategy performance are cost, delivery, flexibility and quality.

In manufacturing strategy, literature the term "manufacturing flexibility" has been defined in a number of ways by several researchers (Gerwin, 1993; Suarez *et al*., 1996; D'Souza and Williams, 2000; Vokurka and O'Leary-Kelly, 2000). The very first definition of the term appeared in 1978 by Mandelbaum as "the ability of a manufacturing firm to respond to environmental changes". Further, Slack (1993) defined the concept as "the ability to take up different positions" or alternatively, "the ability to adapt to range of states". Again, Gupta and Goyal (1989) use the definition of "the ability of a manufacturing system to cope with changing circumstances or instability caused by the environment". In the decade of 90, definition of the term was given further refinement. Upton(1994) proposed that manufacturing flexibility is "the ability to change or react with little penalty in time, effort, cost or performance". In first decade of the 21st century, the advancement in the definition was witnessed in the literature. Swamidass (2000) defined manufacturing flexibility as "the capacity of a manufacturing system to adapt successfully to changing environmental conditions as well as changing product and process requirements". Zhang *et al*. (2003) use the definition as "the ability of the organization to manage production resource and uncertainty to meet various customers' requests". Boyle and Scherrer-Rathje(2008) defined "Manufacturing flexibility is the capability of a manufacturing system or facility to effectively address uncertainty from a wide variety of sources, yet continue to produce efficiently different products or product volumes of acceptable quality, cost, and timeframe."

Classification

Flexibility is a firm's ability to provide a wide range of products, production outputs and delivery options. Several types of flexibilities have been defined in literature (Sethi and Sethi, 1990, D'Souza and Williams, 2000; Narain *et al*., 2000). As an example, manufacturing flexibility has been categorised into internal and external (Upton, 1995; Chang *et al*., 2003, 2005). As per this categorisation of manufacturing flexibility, internal flexibility is an internal attribute of a firm and it is not directly related to market demand. Further, Internal flexibility includes flexibilities such as machine, component, material and routing flexibility and it indirectly aims to fulfil customer requirement more efficiently. On the contrary, external manufacturing flexibility is directly related to customer needs and it affects a firm competitiveness directly (Upton, 1994; Chang *et al*., 2003; Chang *et al*., 2005; Schmenner and Tatikonda, 2005). Examples of external flexibility are new product flexibility, product mix flexibility and volume flexibility. Similarly, flexibility has also been categorised into hard flexibility and soft flexibility (Slack, 1983). Hard flexibilities are directly measurable whereas soft flexibilities are less directly observable and thus difficult to measure. In addition to this, flexibility has also been divided into short-term flexibility and long-term flexibilities depending on the time frame of the flexibility by several authors (Boyle *et al*., 2008; Slack, 2005; Hutchison and Das, 2007). Short-term flexibility includes flexibilities like product flexibility or adaption flexibility, which operates at operational level. Whereas, long-term flexibility includes flexibilities like process flexibility, volume flexibility or production flexibility, which are

related to long run strategic decisions. Recently Iravani *et al*. (2005) presented a new perspective on flexibility in manufacturing and service operations by exploring a new type of operational flexibility that they termed as "structural flexibility (SF) They focussed on strategic-level issues of flexibility that can be implemented using multipurpose resources like cross-trained labour, flexible machines, or flexible factories.

Firm Performance

Performance is a multidimensional construct (Venkatraman and Ramanujam, 1987). Venkatraman (1990) advocated the use of return of assets, operating income, cost per sales and sales per employee for the measurement of business performance. In research studies, firm performance has also been measured relative to competitors using constructs like return on assets, return on investment and return on sales. Some researchers have used financial indicators like sales growth, return on assets, return on sales, return on investment, profit per share and non-financial indicators like market share or new product development performance for the performance measurement of a firm, while examining the relationship between flexibility and performance (Bergeron *et al*., 2003; Llore´ns *et al*., 2005; Patel,2011). Ling-yee and Ogunmokun(2008) has used economic performance and innovation performance criteria for measuring a firm's performance. In economic performance, they have studied production objectives like increased profitability, increased market share, reduced unit costs, and increased capacity utilization whereas in innovation performance they have considered product development objectives in terms of development of new products and modification or up gradation of existing products. Nayak and Ray (2010) have considered finance based, time based, process based and product based constructs to analyze a firm's performance in auto industry. They have used efficiency, effectiveness, productivity, profitability as a measure of performance. In studies, performance has also been measured in terms of internal and external performance. Internal performance measures include quality, cost, delivery time whereas external measures includes sales, market share, sales growth, profit margin, return on investment (Hutchison and Das, 2007;Larso *et al*.,2008; Machuca *et al*.,2011). In addition to the financial performance, non financial measures such as satisfaction performance and lead time performance have also been used by the authors in examining the impact of manufacturing flexibility on firm performance (Fantazy *et al*. 2009; Camiso´n and L'opez, 2010).

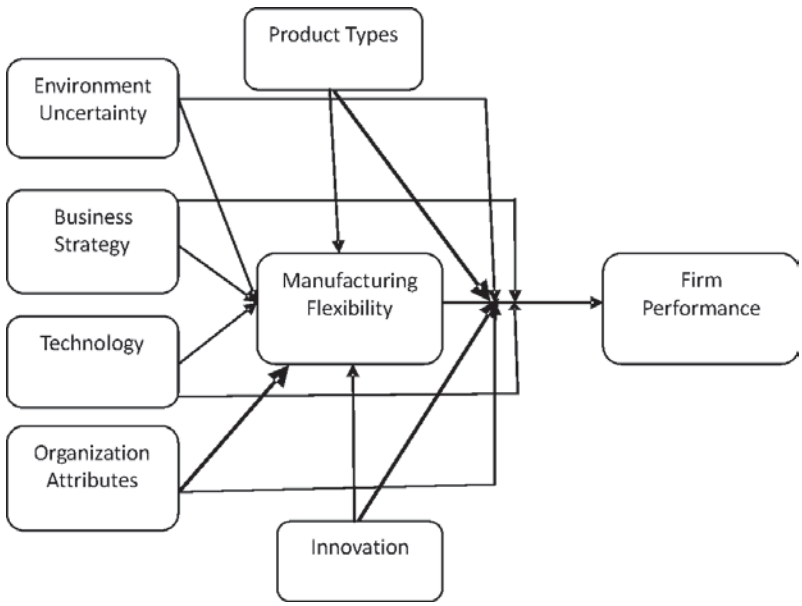
Manufacturing Flexibility and Firm Performance

The concept of fit has originally emerged in contingency theory studies (Venkatraman and Camillus, 1984; Drazin and van deVen, 1985). Contingency theory has been most commonly used in the study of organizations for determining the fit (Patel, 2011). "Fit" suggests the congruence or consistency between two or more factors and a good fit among these factors is assumed to positively affect the performance of the firm.The strategic effectiveness of an organization depends on fit or compatibility of structures and processes of an organization within the firm and outside the firm i.e. the environment in which the firm operates (Miller, 1992). As per contingency theory there should be fit between a company's structure and its environment (Drazin and van de Ven, 1985). Miller (1992) differentiated between external fit that links environment to structure and internal fit that links structure to processes. Studies adopting the fit perspective examine consistency among subsystems within a firm (internal fit) and fit among the organizational structure, strategy and the external environment (external fit).Thus, Fit can be defined as the degree to which an organization is able to matches resources and capability with the opportunities available in the market. A study of literature indicates that similar type of flexibility is not suitable in all environments (Suarez *et al*.,1996; Pagell and Krause,1999,2004). Thus, the relationship between flexibility and performance should be studied

on case-by-case basis with a view that different dimensions of flexibility may influence a firm's performance differently and in a very individualistic manner. (Beach *et al*., 2000). As an example, firm volume flexibility can improve firm performance only if firm is actually facing demand uncertainty. Further the overall organizational strategy of a firm also needs to be examined along with the firm's environment characteristics for studying the overall flexibility of a firm.(Narain *et al*., 2000). As an example, a firm pursuing low cost strategy is required to adopt economics of scale for high volume production. Therefore, it needs low level of flexibility in production system overall. Gerwin (1987) initially pointed out the factors that influence the values of flexibility types. He argued that types of manufacturing flexibility depended on the "nature of a firm's internal operations and external environment". Further, using a contingency theory as a basis, Vokurka and O'Leary-Kelly (2000) have proposed a conceptual model which tries to address shortcomings of earlier existing frameworks of flexibility. This framework is governed by two primary principles. The first principle relates to the forces that guides the four exogenous variables (strategy, organizational attributes, environmental factors and technology) and manufacturing flexibility. Though some firms fail to implement the right form of flexibility but they cannot altogether eliminate the detectable relationship between exogenous variables and manufacturing flexibility. On the other hand, second principle is based on the forces that moderate the manufacturing flexibility and firm performance relationship. Thus, the above framework suggests that firms, which are able to achieve appropriate fit between manufacturing flexibility and the four exogenous variables (strategy, organizational attributes, environmental factors and technology), are able to demonstrate higher level of performance. All these factors have empirically studied in a number of studies but there is very limited available research on all the factors combined.

Further, innovation and product types are the other factors that affect the flexibility and performance relationship. Although few studies are present, in the literature that shows the moderating relationship of innovation and product types on flexibility and performance. Therefore, it can be inferred from the literature that there are six variables that guide the manufacturing flexibility and affect the manufacturing flexibility and performance relationship.

Conceptual Framework: *Manufacturing Flexibility and Firm Performance*



Environmental Uncertainty and Manufacturing Flexibility

Environment uncertainty is a multidimensional concept (Bourgeois, 1980; Anand and Ward; 2004) consisting of dimensions like market, government, regulations, technology etc. Further, environment uncertainty can be classified into several categories based on the management perception of possible future events (Vokurka and O'Leary-Kelly, 2000). In literature, researchers have focused on various uncertainty issues arising from different sources such as consumers, suppliers, technologies and competitors. Miller and Droge (1986) have defined environmental uncertainty based on five dimensions – market, product, competition, consumer and production/ service. Chen and Everett (1991) suggested two types of environmental uncertainty - environmental uncertainty with regards to market and uncertainty arising due to manufacturing processes. Gerwin (1993) has categorized environmental uncertainty into seven dimensions - uncertainty about market acceptance of product, uncertainty regarding product life cycle, uncertainty arising due to customization/product specification, uncertainty of aggregate demands, uncertainty of machine breakdown, and uncertainty about the product features and finally uncertainty arising due to changes in above six uncertainties. Subsequently, Gerwin (1987) summarised the different kinds of uncertainty and the corresponding flexibility types suitable for managing those uncertainty.

Flexibility Types and Uncertainty

Flexibility Types	Uncertainty
Mix	Uncertainty as to which product will be accepted by customer
Changeover	Uncertainty as to length of product life cycle
Modification	Uncertainty as to which product attributes customer want
Rerouting	Uncertainty with respect to machine downtime
Volume	Uncertainty with regards to amount of customer demand
Material	Uncertainty as to whether the material input into the process meet standard
Sequence	Uncertainty in the delivery time of raw materials

Source: Gerwin(1987)

Further, Cheng *et al*. (1997) argued that environmental uncertainty could be viewed from two different perspectives. Uncertainty from the perspective of the marketing function and other from the manufacturing function that subsequently demand marketing based flexibility which consist of product,volume,mix and expansion flexibility and manufacturing based flexibility that includes machine, material handling, process, labour, routing and programming flexibility.

Further, Kara and Kayis (2004) presented a comprehensive analysis of uncertainty and the recommended the type of flexibility required to cope up with those uncertainly based on market and manufacturing related factors. Their study also recommended various methods, tools and techniques for handling variations and uncertainty in the environment. Similarly, Chang (2011) identified types of external and internal manufacturing flexibility corresponds to external and internal environmental uncertainty.

Environmental Uncertainty and Flexibility need

Internal-Manufacturing Process Related	External –Market Related	
Machine downtime, material characteristics, departmental coordination, and resource acquisition and distributor problem	Factors include competitors, consumers, technology, economic policies, product market and demand, customization, short delivery time, society, and uncertain regulations.	Uncertainty
Flexibility that the system needs, including machine flexibility, labour flexibility, material- handling flexibility, routing flexibility, and process flexibility.	Required flexibilities are considered as a chain connection between Corporation strategy, marketing strategy and manufacturing strategy, including product flexibility, volume flexibility, product-mix flexibility , delivery flexibility, demand flexibility, and market flexibility.	Flexibility

Source: Chang (2011)

In an early study, Swamidass and Newell (1987) empirically supported the positive relationship between uncertainty and strategic flexibility and between flexibility and performance in a machine tool industry. Several researchers have argued that managing uncertainty in the environment is the main reason for the existence of flexibility (Gerwin, 1987; Slack, 1989) and they have empirically provided evidence to the positive relationship between manufacturing flexibility and uncertainty being faced by environment (Swamidass and Newell, 1987). However, the results of other studies presented conflicting results (Pagell and Krause, 1999, 2003). Using a contingency theory as a basis Pagell and Krause (1999) concluded that increased flexibility in an uncertain environment did not necessarily lead to higher level of performance. By using a cross industry survey of manufacturers and a series of case studies, their study found no concrete relationship between “fit” and performance. Their study used same measures of environmental uncertainty as used by Swamidass and Newell (1987). However, they examined flexibility only at operational level and not at the strategic level as done by Swamidass and Newell (1987). Later, Pagell and Krause (2004) attempted to extend measurement choice of environment uncertainty to further explore the relationship between environment uncertainty and firm performance. Their study supported the finding of Pagell and Krause (1999) and argued that regardless of measurement choice, or statistical method used, there is no conclusive relationships between uncertainty, strategic flexibility and firm performance. In a comparative study of high and low performing firms in fishing industry, Dryer and Grønhaug(2004) statistically examined the relationship between firm performance and flexibility in a highly uncertain environment. The findings of their study indicate that flexibility is a valuable skill, which has major impact on competitive positioning of firms. In order to outperform in a competitive environment, there must be a good match and balance between types of flexibility developed at the firm level and factors of uncertainty. Chang (2011) measured the linkage between manufacturing flexibility and environmental uncertainty for a food company. Using quantitative approaches like quality function deployment (QFD), analytical hierarchy process (AHP), and grey relational analysis (GRA), their study suggested the means to improve the flexibility of a manufacturing system to cope up with environmental uncertainty. In addition, findings of the study provided tools to prioritise different types of manufacturing flexibility that are required for surviving in an uncertain environment.

To summarise, environmental factors deal with environmental uncertainty faced by a firm in the past as well as uncertainty existing currently and the uncertainty expected to be faced by the organization in near future (Boyle, 2006). Different manufacturing situations lead to different

level of uncertainty and variation in manufacturing system. Consequently, the type of flexibility to be employed differs in different manufacturing situation (Kara and Kayis, 2004; Chang, 2011). Therefore, it is essential to determine the dimensions of manufacturing flexibility required to be increased, so as to increase firm performance. The level of performance of a firm depends on its fit between appropriate types of flexibility with the corresponding type of environmental uncertainty confronting the firm (Gerwin, 1993; Dryer and Grønhaug ,2004;Chang ,2011).

Business Strategy and Manufacturing Flexibility

A company's business strategy is the plan used to establish a market position, conduct operations, attract and satisfy customers, compete successfully, and achieve its goals (Mitenburg, 2005). Business strategy has direct effect on the adoption of manufacturing flexibility. Hayes and Wheelwright (1984) first supported the significance of manufacturing flexibility in firm's manufacturing strategy. Literature has suggested the theoretical relationship between manufacturing flexibility and a firm's strategy (Gerwin, 1993; Upton, 1995; Vokurka and O'Leary- Kelly, 2000; Chang *et al.*, 2003). Firm develops manufacturing flexibility in its manufacturing process to respond to uncertainties. Further, appropriate fit between a firm's business strategy and its flexibility is very important for increasing a firm's performance (Gerwin 1993; Chang *et al.* 2003; Zhang *et al.* 2003; Sawhney 2006; Goyal *et al.*, 2006). Gerwin (1993) categorized strategy for firms into four types based on the relationship between a firm's strategy and the kind of flexibility employed by it. The four generic strategies labeled as adaptation, redefinition, banking, and reduction are classified based on their defensive or proactive nature. Further, Ettlie and Penner-Hahn (1994) conducted exploratory studies to empirically examine the relationship between manufacturing strategy and various measure of new manufacturing system flexibility in durable goods plant. They looked at degree of focus of a plant and arrived at the conclusion that the more focused is a firm's manufacturing strategy the lesser the need of manufacturing flexibility. Their study led to the result that the quality and cost focuses of manufacturing strategies are not related to manufacturing flexibility. Thus, several strategic factors need to be considered before planning and implementing manufacturing flexibility (Suraez *et al.*, 1996). Using a large-scale survey of 269 firms, Gupta and Somer (1996) examined the impact of firm's business strategy on firm's internal flexibility. Business strategy has direct impact on manufacturing flexibility and manufacturing flexibility in turn indirectly affects business performance of a firm. They suggested that the impact of business strategy on manufacturing flexibility depends on the types of business strategy followed by a firm. However, they have not focused on the linkage between different types of strategies and different dimensions of manufacturing flexibilities.

The flexibility is a multidimensional concept and companies should select types of flexibilities consistent with the business strategy of the firm (Chang *et al*, 2003; Fantazy *et al.*, 2009). Chang *et al.* (2003) in their study of small and medium manufacturing companies investigated the effect of manufacturing flexibility on business performance under three different business strategies labelled as low cost strategy, differentiated strategy and first mover strategy in machine tool and machinery industries in Taiwan. They have examined the relationship between three business strategies and six types of manufacturing flexibility. The finding of the study provides evidence that more flexibility does not necessarily improve firm performance. In order to improve firm performance it is important to have a proper match between the dimension of manufacturing flexibility and the type of business strategy adopted by a firm. As an example, volume flexibility is not useful for firms following differentiation strategy while it benefits firms following first mover strategy. On the other hand, if a firm is pursuing a low cost strategy then it will strive to achieve economies of scale. In this case, the need of flexibility will be much less. In support of this, using a contingency theory and competence and capability as basis, Ling-yee and

Ogunmokun (2007) conducted a study to determine the conditions that foster manufacturing flexibility and the way in which firms support it. The finding of the study suggests that the low cost strategy of a firm with an aim to achieve economies of scale actually weakens the firm's ability to transform its manufacturing competence for achieving product range flexibility. Further, Fantasy *et al*. (2009) examined the relationship among three types of strategy labelled as innovative strategy, customer oriented strategy, follower strategy and supply chain flexibility and performance (financial and non-financial) in supply chain context. Using a path analysis technique from a sample of total 175, small and medium-sized Canadian manufacturing companies the study provides evidence that strategy directly affects flexibility dimensions that in turn affects performance of the firm. The finding provides evidence of direct effect of strategy on flexibility and then direct effect of flexibility on performance. As an example, firm following innovative strategy must invest time and resources in new product and delivery flexibility while customer oriented strategy firms need to invest heavily on sourcing, product and delivery flexibility.

Manufacturing Technology and Manufacturing Flexibility

Vokuka and O'Leary-Kelly (2000) indentified that technology significantly affects the type of manufacturing flexibility required. It includes capability to implement flexible manufacturing systems, advance manufacturing technology and issues like the scale and age of technology, technology complexity, and interdependence and work flow integration. Advanced manufacturing flexibility has been considered as an antecedent to the manufacturing flexibility. The term "advanced manufacturing technology" includes computer-controlled systems used for design and manufacture, current manufacturing practices such as JIT production system, and the use of real-time information to eliminate waste and implement a pull system in a plant (Narasimhan *et al*., 2004).

In an empirical study, Suarez *et al*. (1995) found that higher levels of advanced manufacturing technology were positively correlated with greater volume flexibility. On the contrary, it was associated with less mix and new product flexibility. The purpose of investment in AMT was to run long production batches, rather than exploiting its potential to increase mix and new product flexibility. Further, Safizadeh *et al*. (1996) identifies that continuous flow plants utilize advanced manufacturing technologies to attain high mass customization. The research witnessed that the companies having advanced manufacturing technology improves flexibility level in a firm. However, conflicting opinions have also emerged (Swamidass, 1988; Upton, 1995, 1997; Boyer *et al*, 1997). Upton (1995, 1997) found negative relationship between manufacturing technology and product and production flexibility. Similarly, Boyer *et al*. (1997) did not find any significant relationship between advanced manufacturing technology and flexibility. Advanced manufacturing technology along with improvement in operational practices play an important role in high firm performance. Using a large-scale survey Zhang *et al*. (2006) examined the role of advance manufacturing technology and operation improvement practices in improving firm performance. The study indicates that firm having high level of operation improvement practice and advance manufacturing technology achieve higher performance than firm with low levels of operation improvement practices does. Further, Cordero *et al*. (2009) mentioned that advanced manufacturing along with competent worker and organizational technology improves the manufacturing flexibility of the firm. The findings of the results suggest that if a firm is willing to enhance its manufacturing flexibility using advanced manufacturing technology then it should have compete workers to work on advanced manufacturing technology. Since advanced manufacturing technology involves very high price, the advanced manufacturing technology implementation may not be reasonable unless AMT are more extensively used for increasing manufacturing flexibility. In addition, firm should be careful about adopting operational technologies

and staffing of competent worker because operational technology partially restricts the extent to which competence worker can increase manufacturing flexibility. The reason behind the diversity of results is the moderating influence of multiple factors like the purpose of technology adoption (Dean,1987;Cordero *et al.*,2009), lack of strategic clarity(Adler,1988),worker's training, empowerment and job enrichment (Ward *et al.*,1994) between the relationship of advanced manufacturing technology and manufacturing flexibility.

Organizational Attributes and Manufacturing Flexibility

Human and organizational factors play very crucial role in realizing manufacturing flexibility goals (Upton, 1995). It broadly refers to the design characteristics of a firm as well as the behavioural aspects of a firm (workforce skills and experience, managerial actions and interaction) involving the people within the organization (Vokurka and O'Leary- Kelly, 2000; Boyle, 2006). It incorporates the non-technological factors like size of the organization, ownership structures, management support, workforce experience, information sharing etc.

The study conducted by Suarez *et al.* (1996) at plant level in a printed circuit board industry addressed the empirical relationship between flexibility and non-technological factors. Based on the findings of their study they suggested that non-technological factors like high workers involvement in problem-solving activities, close relationships of workers with suppliers, and flexible wage schemes, appeared to increase mix, volume, and new-product flexibility. Upton (1997) further measured the relationship among process range flexibility and structure, infrastructure and managerial policy in a fine paper industry. The evidence suggested that flexibility was strongly negatively related to scale and positively related to workforce experience. Other than workforce experience, ownership structure has also been found as other deciding criteria. The type of ownership structure also affects the flexible production. Kathuria and Partovi (1999) argues that some practices, such as relationship-oriented practices and participative leadership and delegation practices, are more effective in managing work when the emphasis is high on flexibility. The use of work-oriented practices—problem solving, clarifying, monitoring, informing, and planning—by manufacturing managers does not have any significant impact on their performance when the situation is characterized by flexibility.

Ling–yee *et al.* (2008) measured ownership structure of the firm as a moderating variable for determining the impact of manufacturing flexibility on firm performance. The result of the study suggests that private enterprise having greater control and autonomy enable efficient resource allocation for flexible production than the state enterprise. In addition to the control structure, continuous commitment from top management is essential for any organizational initiative. Drucker (1969) was the one who first advocated that importance of support of top management in any organizational activity. Further, support from top management for contingency planning play an important role for successful implementation of any management program and it is positively related to flexibility(Min and Mentzer, 2004; Skipper and Hanna, 2009) . Manufacturing flexibility may provide competitive advantage to the firm if there is proper information sharing among organizations about the possible future events, best practices and potential disruptive events. Further, Information sharing has been defined as the willingness to make strategic and tactical data available to others involved in the planning process (Skipper and Hanna, 2009).

Product Types and Manufacturing Flexibility

If the organization is engaged in developing new products frequently then the type of new product also affects the relationship between manufacturing flexibility and performance of the firm. Studies have shown that new products referred to as radical require considerable changes in organizational structure and processes (Nord and Tucker, 1987). It is more risky, unpredictable

and uncertain than incremental products. In addition, it requires more time to develop because of the need to develop new capabilities (Sivadas and Dwyer, 2000). Early studies on new product development categorised products into three categories: product having a low level of novelty, products that are incrementally improved over existing products and those that are having high level of novelty. Larso *et al*. (2009) highlighted the complexity of the relationship between manufacturing flexibility and new product performance. New product type was found to affect the relationship between flexibility and performance. In particular, the result of the study suggest that for the electronic manufacturers developing radically new products, increased levels of machine, new product, and modification flexibility will positively impact new product performance, as measured by quality and market success. Other improvements in flexibility, however, were not found to have any effect on product performance. In contrast to this, increase in machine, volume, operation and labour flexibility were actually found to negatively impact some aspect of new product performance for incremental new products.

Innovation and Manufacturing Flexibility

In a highly dynamic market, it is imperative for a firm to engage in continuous or periodic innovation. Van de Ven (1986) defined innovation as the adoption of an idea or behavior that is new to the organization and is a critical mechanism through which firms secures a place in the competitive world of the future. Innovation can be either incremental involves refining, improving and exploring an existing technical trajectory or radical that disrupts an existing technological trajectory.

Dynamic capability view suggests that firm will able to achieve the superior performance only by persistently renovating its resources and capability base. Teece and Pisano (1994) explain that winner in the global market place have been firms demonstrating timely responsiveness and rapid and flexible product innovation. Therefore, manufacturing flexibility will only produce extraordinary results when it is applied with the innovation (Bayus *et al.*2003). Bolwijn and Kumpe (1990) proposed a phase model that argues that innovativeness would be the new market demand in addition to the already existing ones of efficiency, quality and flexibility.

Phase Model

	Market Requirement	**Performance Criteria**	**Firms(Ideal Type)**
1960	Price	Efficiency	The efficient firm
1970	Price ,Quality	Efficiency + Quality	The Quality Firm
1980	Price, Quality, Product Lines	Efficiency +Quality+ Flexibility	The flexible firm
1990	Price, Quality, Product Lines, Uniqueness	Efficiency + Quality + Flexibility + Innovative Ability	The innovative firm

Source: Blowijn and Kumpe (1990)

Suarez *et al*. (1996) measured the impact of AMT on manufacturing flexibility in a printed circuit board industry. The findings of the study suggests that increase in the innovation of manufacturing technology and production process may reduce the lead time necessary to modify the existing products, develop new products, and change production levels, and consequently enhance product mix, new product, and volume flexibility. In a manufacturing flexibility literature, a very few amount of work has been done on the empirically defining the relationship between manufacturing flexibility and innovation. In a large-scale survey, Camiso´n and Lo´pez (2009) measured mediating role of three types of innovation (product, process, and organizational) on the relationship between manufacturing flexibility and firm performance. By using a structure equation modelling they have concluded that effect on organizational performance of adopting a

flexible productive system is mediated by incorporating product, process, and organizational innovation. The study argues that adopting a flexibility manufacturing system will not guarantee improvement in firm performance and their productivity is linked to the complementary introduction of innovation.

Findings

This literature review of manufacturing flexibility aims at providing more than just a listing of extant publications. From the above literature review, it can be inferred that the integrated framework of manufacturing flexibility and firm performance is largely missing from contingency perspective. There are many literatures supporting the fact that the relationship between manufacturing flexibility and firm performance is contingent on several exogenous variables. However, the question remains unanswered about how these variables interact among themselves. Most of the studies have been conducted in isolation by taking into account one out of these exogenous variables that affects the manufacturing flexibility-performance relationship. Thus, a comprehensive picture is still largely missing.

Further, different kind of manufacturing situation brings different kind of uncertainty for a manufacturing firm. Thus, the need of manufacturing flexibility differs in different manufacturing environment. By going through various studies, it may be concluded that the relationship between environment uncertainty and manufacturing flexibility is industry specific and in some case, the findings may differ even in the same industry. Therefore, it is difficult to conclude anything without considering industry specific factors. Though many studies support the view that uncertainty in the environment is positively associated with the manufacturing flexibility, a very limited number of the studies has empirically addressed the question of fit between appropriate types of flexibility and the corresponding type of environmental uncertainty. In addition, there has been found to be many dimensions of flexibility in various literatures, thus, it is essential to determine which dimension of flexibility needs to be increased for better firm performance.

Although there are some literature which has shown the fact a good fit between strategy and manufacturing flexibility enhances firm performance, but the strategy concerns of manufacturing flexibility and performance relationship has not been much explored in the literature. The nature of competitiveness, macro and micro industry structure and life cycle of products varies from industry to industry, there is a need to further explore the strategy concern of manufacturing flexibility and performance relationship in other industries also.

“Technology” has been covered in manufacturing flexibility research from the beginning. The findings across various studies demonstrate inconsistent findings as there are several factors that can moderate the relationship between advanced manufacturing technology and manufacturing flexibility. (Dean, 1987; Ward *et al.*, 1994; Cordero *et al.*2009). Thus, there is a need is to understand whether and how various factors moderate the effects of advanced manufacturing technology on manufacturing flexibility.

Further study conducted on the relationship between organizational attributes and manufacturing flexibility is limited to a particular industry. Although, the research has so far focused on several organizational attributes such as size of the organization, workforce experience, managerial emphasis on problem solving, information sharing etc. but it is still remains unanswered that findings of result are generalizable in other industry or not.

Product types concern in manufacturing flexibility literature has been explored mainly related to new product performance. It would be helpful in further understanding how different dimensions of flexibility might interact for a given type of new product and for multiple aspect of performance.

Further literature on manufacturing flexibility gives an initial support for the existence of contingency-based relationship between manufacturing flexibility and the Innovation capability adopted by a firm. However, a very limited published study examines this relationship. Further, this study uses variables that have been obtained by means of subjective appreciations. Thus, research must use objective measure of variables to study a meaningful relationship between manufacturing flexibility and the Innovation capability of a firm.

Conclusion

Many authors have identified the need to study the complex nature of manufacturing flexibility - performance relationship and the role of moderating variables like uncertainty, technology, strategy, organizational attributes, product types and innovation in this relationship. Research findings suggest that different dimensions of manufacturing flexibility have different importance in different competitive settings. Thus, there should be a proper fit between environmental uncertainties, internal strategy, organizational, and technology and manufacturing flexibility to improve firm performance.

In this light, the relationship between a firm's manufacturing flexibility and performance should be developed only after capturing and studying the company's practices in detail. Therefore, the present study also recommends the incorporation of company's practices into the relationship of manufacturing flexibility and performance.

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