CHAPTER – II
LITERATURE REVIEW

2.1 Introduction

Results of any research can be useful only when relevant previous literature on it is reviewed and analyzed. This chapter is an attempt to record in brief what has been reported in the research literature on the various aspects of manufacturing flexibility and elucidate its interaction with new technology and sourcing practices in manufacturing industry. A methodical review on the concept, taxonomy and related facets of technology and sourcing practices has also been incorporated. The literature has also been reviewed on the methodologies to be used in carrying out the research.

The literature reported has been organized into the following broad headings:

- Concept of flexibility
- Manufacturing flexibility, its types, nature and taxonomy
- Technology, technology adoption, categorization and use of AMTs, linkages with manufacturing performance
- Sourcing practices, its types, nature and linkages with flexibility aspects

Based upon the description of all related concepts, models, frameworks proposed by the researchers related to research topic, a conceptual framework have been developed and explained in the chapter.

2.2 Flexibility

The development of the concept of flexibility in the literature has been slow until the late 1970s because of the relatively stable market structure and minimal competitive pressure that existed. Flexibility was seen to be increasingly important after Hayes and Wheelwright (1979) suggested that the characteristics of production systems tend to evolve as products go through their product life cycles (i.e. introduction, growth, maturity, and decline). As the production system evolves along with the product life cycles, the appropriate manufacturing strategy will change as well. In addition, the shorter product life cycles of today’s consumer products demand a more flexible manufacturing strategy to accompany fast product development and new product introductions (Calantone et al., 1994).
An increasing number of manufacturing managers recognize that achieving low cost and high quality is no longer enough to improve or sustain their firms’ competitive positions. As the competitive environment continues to change rapidly and unpredictably, managers are increasingly concentrating on flexibility as a way to achieve new forms of competitive advantage. There has been an increasing concern in the academic and management studies literatures with the notion of flexibility (Sethi and Sethi, 1990; Gerwin, 1993; Jordan and Graves, 1995; Upton, 1995; Dangayach and Deshmukh, 2001; Gerwin, 2005; Vokurka et al., 2007). Flexibility is regarded as a positive feature since it contributes to the organization’s ability to absorb or even benefit from variations in its environment. Some of the definitions of flexibility include:

- Flexibility has been characterized as “doing things fast” and “being responsive to the market” (Bower and Hout, 1988; Stalk, 1988).
- Adler (1988) claims that flexibility has to be understood against a backdrop of stability. Thus flexibility should be seen as a type of response to environmental variations that enables a measure of adaptability without causing undue disruption to organizational processes.
- Flexibility is generally regarded as the ability to respond to or conform to new situations and is usually classified as process, product, or infrastructure related (Noori and Radford, 1995).
- Zhang et al. (2006a) perceives flexibility as the organization’s ability to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses.

2.2.1 Operationalizing Flexibility

The idea of flexibility in an organizational context refers to the ability to precipitate intentional changes, to continuously respond to unanticipated changes, and to adjust to the unexpected consequences of predictable changes (Bahrami, 1992). According to Bahrami, flexibility is a polymorphous concept whose meaning varies according to the situation. For example, flexibility means being fast on one’s feet, able to move rapidly, change course to take advantage of an opportunity or to side step a threat. This capability is critical for enabling ‘time based’ competition, facilitating rapid response and reducing product development cycles. It also refers to the ability to quickly redefine a position and reform in the midst of a dynamic engagement. Flexibility also implies the ability to be
versatile able to do different things and apply different capabilities depending on the needs of a particular situation. On the defensive side of the spectrum, flexibility refers to the qualities which enable an enterprise to endure when negatively affected by change. Flexibility has been an elusive quality in manufacturing and operations. The term has come to be used for many purposes, each of which characterizes a different quality or capability of a system. (Upton 1994).

Flexibility has long been a concern of operations management writers. At a broad level, flexibility can be understood as an absorber of environmental uncertainty and variability (Gerwin, 1993; De Toni and Tonchia, 1998; Beach et al., 2000). The operations management and related literatures are largely united in identifying as the motivation for increased flexibility, the existence of a market or environment which is uncertain, unpredictable or turbulent. Flexibility is regarded as a positive feature since it contributes to the firm’s ability to absorb or even benefit from variations in its environment.

In their extensive review, De Toni and Tonchia (1998) advance two general perspectives on flexibility:

(1) As characteristic of the interface between a system and its external environment (Correa 1994). In this case, flexibility acts as a filter, buffering the system from external perturbations. Flexibility thus functions as an absorber for uncertainty. The external perturbations are characterized by: (1) measure, (2) frequency, (3) novelty, (4) certainty;

(2) As a degree of homeostatic control and dynamic efficiency of a system (Mariotti 1995). Reference is made to a cybernetic system, namely one which incorporates mechanisms of measurement, control and regulation aimed at homeostasis that is to say at the preservation of an existing state in the presence of exogenous changes. Flexibility is thus mainly understood as a degree of cybernetic adaptation.

One typical way of operationalizing the broad definition of flexibility offered above is by focusing on the ability to change “the nature, volume and timing of the output” of an operation (Slack and Corrêa, 1992). Upton’s (1994) oft-quoted definition is “flexibility is the ability to change or react with little penalty in time, effort, cost or performance”. Upton (1995) discusses different strategies for a firm may to become flexible and suggests that flexibility is both a multidimensional and multilevel attribute. Upton’s arguments suggest that flexibility is enacted as a response to different classes of problems and there are usually multiple responses to the same set of problems.
2.2.2 Multidimensional Perspective on Flexibility

Slack (1984) proposed a multidimensional perspective on flexibility, arguing that flexibility has three dimensions, (1) the range of possible configurations a system can adopt, (2) the cost of migrating from one configuration to another, and (3) the time needed to make the transition. One system is more flexible than another if it can handle a wider range of configurations, accommodate change in a shorter amount of time, or make the transition at lower cost. The time and cost dimensions are inversely related, in that the time to make a transition may be shortened at extra cost, and the cost of making a transition may be reduced by allowing more time for the change. Due to its multidimensional nature, flexibility is inherently difficult to measure. Because flexibility is most often not an end in itself, the impact of flexibility should be measured with respect to other performance criteria such as product quality, volume, and delivery.

Gupta and Buzacott (1989) extended Slack's notion by characterizing flexibility in terms of sensitivity and stability. Sensitivity refers to the level of change a system can accommodate before corrective action is required. Stability refers to the magnitude of change that a system can handle while still maintaining normal performance. Defined in this way, sensitivity and stability represent the minimum and maximum magnitude of change for a system within which the property of flexibility holds (Kumar, 1987). Similarly, Upton (1994) stressed the difference between robustness and agility. The former emphasizes the ability to maintain the status quo despite changes; the latter emphasizes the ability to initiate change rather than react to it. Carlson (1989) draws on two types of flexibility: type I (static) flexibility is concerned with routines for dealing with foreseeable events and type II flexibility (dynamic) relates to the capacity to react to unpredictable environmental or technological changes.

Gerwin (1993) proposed a conceptual model that places flexibility within a broad context. The model includes five variables: environmental uncertainty, strategy, required manufacturing flexibility, methods for delivering flexibility, and performance measurement. Flexibility is typically defined as an adaptive response to environmental uncertainty by Gupta and Goyal (1989). However, Gerwin expanded this definition by arguing that an enterprise could leverage flexibility to anticipate and prepare for environmental uncertainties through redefinition. Gerwin also considers four generic flexibility strategies: adaptation, redefinition, banking, and reduction. Adaptation represents a defensive approach, incorporating the traditional use of flexibility to adjust to
uncertainty. Redefinition is defined as the proactive use of flexibility to change the basis of competition. Banking involves the strategic investment in flexibility, which is then held in reserve for future needs, thus creating new options for the organization. With a reduction strategy, the organization uses other means for reducing environmental uncertainty (e.g., through long-term contracts with customers and suppliers, design for manufacturability, or preventive maintenance), thus decreasing the need for flexibility.

De Groote (1994) defined flexibility as a hedge against environmental diversity and proposed a general framework for analyzing flexibility. The framework consists of three elements: (1) the set of technologies whose flexibility is to be evaluated, (2) the set of environments in which those technologies operate, and (3) a performance criterion for evaluating different technologies in different environments.

There are also some manufacturing concepts that are similar to flexibility. However, whilst they are not mutually exclusive concepts, they do differ in a number of important aspects. Spring and Dalrymple (2000) review the literature covering manufacturing strategy, flexibility, flexibility and agile manufacturing concepts. Consequently they make the following distinction between each concept:

- **Flexibility** – the capacity to deploy or re-deploy production resources efficiently as required by changes in the environment.
- **Total flexibility** – the ability to deliver high-quality product tailored to each customer at mass-production prices.
- **Agility** – the ability to alter any aspect of the manufacturing enterprise in response to changing market demands.
- **Flexibility/agility** – an ability to adapt rapidly and with constant coordination in an environment of constant and rapid changes.

Gerwin (2005) has made an attempt to link flexibility requirements with manufacturing process design. Each aspect of flexibility is associated with design constraints on the nature of workforce and equipment. Vokurka et al. (2007) stresses upon the widening of flexibility approach beyond manufacturing to overall flexibility and suggested low cost and high quality products, improved responsiveness to customers as main strategic imperatives.
2.2.3 **Systemic Flexibility**

Sushil (1994) presented the concept of systemic flexibility. According to him, the flexibility in the systemic sense cannot be generated by attaching ourselves to a point on the continuum. The flexibility is generated in the system by virtue of the existence of the continuum. The success lies in making a dynamic balance between the polar extremes. Thus, systemic flexibility is the exercise of free will or freedom of choice on the continuum to synthesize the dynamic interplay of thesis and antithesis in an interactive and innovative manner, capturing the ambiguity in systems, and expanding the continuum with little penalty in time and efforts. Such a systemic concept of flexibility will have major attributes of spectral, integrative, interactive, innovative, and fuzziness character. Based on that, a flexible system methodology has been developed by Sushil (1997b) which acts as a research methodology for flexible systems management. This methodology tries to resolve the end of continuum paradoxes, by treating all the system based methodologies and techniques as lying on a continuum ranging from hard to soft, and all the problem situations also on a continuum ranging from well structured to unstructured. The three basic components that define dynamic interplay of reality in flexible systems management paradigm are situation, actor and process. They interact flexibly on multiple planes in the ambiguous reality and ultimately melt together into one at the enlightened stage. The boundaries between the three basic components are fuzzy. The engineering enterprise, which is the actor under consideration, forms a part of the situation as well as the process. These three are parts of an inseparable whole. The management in this paradigm can be explained from the point of view of either the situation, or actor, or process. The situation is to be managed to an organic order by an actor through a flexibly evolved self-organizing management process which recreates the situation. The actor understands the ambiguous situation through deep involvement, thinking of general qualitative patterns through reasoning by analogy and exercises the freedom of choice to flexibly and systemically evolve a management process on the continuum in an interactive and innovative manner for generating an organic order in its own reality. The process is a flexible and self-organizing system of management that is to be evolved by an actor using its internal and external flexibility for managing situation in ambiguous and dynamic reality, which mutually influences the process and the actor.
2.3 Manufacturing Flexibility

The approach to manufacturing has under gone a considerable change in the past decade or so. Fast and dramatic changes in customer expectations, competition, and technology are creating an increasingly uncertain environment. In order to be competitive, manufacturing enterprises need to respond rapidly to product demand changes. The importance of flexibility in manufacturing has been well documented (Sethi and Sethi, 1990, Hill and Chambers, 1991, Dixon, 1992, Gupta and Somers, 1992, Gerwin, 1993, Chambers, 1992, Sushil, 1997, and Narasimhan, 2004) and its effectiveness in providing several benefits like reduction in set-up time, manufacturing lead-time, equipment idle-time and inventory levels, improvement in productivity, and better control of the process have been adequately demonstrated. In fact manufacturing flexibility as a strategy remains high on the agenda of many manufacturing organization (Beach et al., 2000). Schmenner and Tatikonda (2005) have revisited Gerwin’s (1987) conceptualization of manufacturing flexibility and subsequent progress in understanding it and found that many of Gerwin’s insights have stood the test of time; nevertheless, manufacturing flexibility has a bigger meaning now than it did 20 years ago. It has spread throughout the supply chain and into product development. And, it now encompasses the complementarily of “flexible” and “proactive” factories.

Manufacturing flexibility has been heralded as a major competitive weapon for manufacturing organizations operating in increasingly uncertain environments and turbulent markets. It has been argued that manufacturing flexibility has the capability to provide organizations with the ability to change levels of production rapidly, to develop new products more quickly and more frequently, and to respond more rapidly to competitive threats.

2.3.1 Defining Manufacturing flexibility

Most studies on manufacturing flexibility provide implicitly or explicitly stated definitions of the manufacturing flexibility construct. Some representative definitions are presented below.

- An early definition of manufacturing flexibility provided by Zelenovich (1982) defines manufacturing flexibility as the ability of a manufacturing system to adapt to changes in environmental conditions and in the process requirements. This definition is important, since for the first time it takes into account both the exogenous and the
endogenous nature of manufacturing flexibility: the former as a consequence of the market’s demand, the latter as the exploitation of the opportunities offered by technological innovations.

- Gupta and Goyal (1989) who, quoting Buzacott & Mandelbaum (1985), credit Mascarenhas (1981) as having defined it as “the ability of a manufacturing system to cope with changing circumstances or instability caused by the environment” or environmental uncertainties (Barad and Sipper, 1988).

- Cox (1989) defines manufacturing flexibility as “the quickness and ease with which plants can respond to changes in market conditions”.

- Sethi and Sethi (1990) contend that manufacturing flexibility is a hard-to-capture concept. Flexibility of a system is its adaptability to a wide range of possible environments that it may encounter and a flexible system must be capable of changing in order to deal with a changing environment.

- The ability to respond effectively to changing circumstances (Gerwin, 1987; Gupta and Gupta, 1991).

- The capacity of a manufacturing system to adapt successfully to changing environmental conditions and process requirements. It refers to the ability of the production system to cope with the instability induced by the environment (Swamidass, 1988).

- Adopting an operational view, Nagarur (1992) defines manufacturing flexibility as “the ability of the system to quickly adjust to any change in relevant factors like product, process, loads and machine failure”.

- The ability to implement changes in the internal operating environment in a timely manner at a reasonable cost in response to changes in market conditions (Watts et al., 1993).

- In the short run, manufacturing flexibility means the ability to adapt to changing conditions using the existing set and amount of resources. In the long run, it measures the ability to introduce new products, new resources and production methods, and to integrate these into the existing production system (Olhager, 1993).

- Newman et al. (1993) define manufacturing flexibility as a fundamental instrument for dealing with firm uncertainty. The counterbalancing action of flexibility towards uncertainty may be represented by the two plates of a balance, one of which
represents flexibility, and the other uncertainty (both external—of the demand or the supply—and internal—failures, lack of materials, delays).

- Boyle (2001) states that most of the earlier definitions view flexibility as a reactive capability of the management to the uncertainty faced by an organization, ignoring the performance dimensions such as cost, time and quality.
- Flexibility is the degree to which the firm is able to adjust the time in which it can ship or receive goods (Prater et al., 2001).
- Zhang et al. (2003) regard manufacturing flexibility as the ability of the organization to manage production resources and uncertainty to meet various customer requests.

Whilst by no means exhaustive or particularly comprehensive, the above definitions illustrate three important points. They reflect the breadth and diversity in the understanding of the subject, they refer to the ability to respond to change, and they point to the use of flexibility to accommodate uncertainty. The use of flexibility for the purpose of accommodating uncertainty is a notion which has received broad recognition, but the types of uncertainty a system can be expected to address appears to be dependent on the operational level from which it is viewed, e.g. the process cell, the function or the manufacturing plant. Understanding the constituent dimensions of manufacturing flexibility and their interrelationships would be of value to the organizations whose competitive strength depends on flexible manufacturing.

In light of existing literature and scope of this study, the manufacturing flexibility is defined as: ‘the ability of the system to adjust to environmental changes/market fluctuations and process requirements with little penalty in time, effort, cost and performance’.

2.3.2 Manufacturing Flexibility and Uncertainty

Manufacturing organizations have often been indicated to be open systems faced with uncertainty and ambiguity, yet requiring certainty and clarity to operate in a balanced manner (Slack, 1997). In the case of uncertainty, flexibility can be seen as coinciding with the ability to deal with the unexpected, both within the manufacturing system and outside (Toni and Tonchia, 1998). Environmental uncertainty has been argued to be one of the main reasons for a firm to seek flexibility (Gerwin, 1987; Slack, 1989), and some researchers provide certain empirical support for such theories (Swamidass and Newell, 1987). It should, however, be noted that other researchers have failed in showing a significant relationship between environmental uncertainty and actual manufacturing
flexibility in the attempt to validate empirically the relationships between them (Pagell and Krause, 1999).

A broad range of rationales for acquiring flexibility has been suggested. Frazelle (1986) claims flexibility is required in order to maintain competitiveness in a changing business environment, and cites current issues such as a rapidly decreasing product half-life, the influx of competitors, an increasing demand for product changes and the introduction of new products, materials and processes. While Slack (1983) suggests the incentives to seek flexibility are founded in the instability and unpredictability of the manufacturers’ operational environment, developments in production technology such as FMS and robotics, and the widening aims of production to progress beyond cost and productivity issues to manufacturing system flexibility. Gerwin (1987) made an attempt to associate types of uncertainty with types of flexibility and is summarized in Table 2.1.

<table>
<thead>
<tr>
<th>Flexibility Type</th>
<th>Uncertainty</th>
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<tbody>
<tr>
<td>Mix</td>
<td>“Uncertainty as to which products will be accepted by customers created a need for mix flexibility”</td>
</tr>
<tr>
<td>Changeover</td>
<td>“Uncertainty as to the length of product life cycles leads to changeover flexibility”</td>
</tr>
<tr>
<td>Modification</td>
<td>“Uncertainty as to which particular attributes customers want ...leads to modification flexibility”</td>
</tr>
<tr>
<td>Rerouting</td>
<td>“Uncertainty with respect to machine downtime makes for rerouting flexibility”</td>
</tr>
<tr>
<td>Volume</td>
<td>“Uncertainty with regard to the amount of customer demand for the products offered leads to volume flexibility”</td>
</tr>
<tr>
<td>Material</td>
<td>“Uncertainty as to whether the material inputs to a manufacturing process meet standards gives rise to the need for material flexibility”</td>
</tr>
<tr>
<td>Sequence</td>
<td>“Sequence flexibility ... arises from the need to deal with uncertain delivery times of raw materials.”</td>
</tr>
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</table>

An organizational perspective on the rationale for acquiring flexibility is provided by Gunnigle & Daly (1992) who cite the necessity for higher productivity to decrease unit costs; an organization’s need to adapt production strategy to accommodate fluctuations in energy prices, interest rates and inflation; and reduced skill requirements as a consequence of advances in technology. Chang et al. (2002) investigated the strategic choice of aligning flexibility development with the external environment that manufacturing manager’s face considering uncertainties in demand, material supply, competition and new product technology and indicate that the matching of manufacturing flexibility with environmental uncertainty is necessary to ensure profit and sales performance.
Correa (1994) has suggested that environmental uncertainty and variability in outputs are the two main reasons that manufacturing flexibility is sought. These two factors, in whatever form they may materialize, can be translated into types of operational change which can be further categorized according to whether the need for change is planned or unplanned. Unplanned changes, either originating internally or externally, are referred to as stimuli, i.e. the cause of the requirement for flexibility. The sources of stimuli, Correa suggests, can be categorized as either process, labour, suppliers, customers, society, corporate & other functions and competitors. Moreover, unplanned change has five main dimensions: size, novelty, frequency, certainty and rate. Consequently, manufacturing flexibility is viewed as a reactive capability and alternative uses of it or requirements for it are not considered in any detail.

Kara and Kayis (2004) provide a comprehensive analysis of variability and uncertainty, and therefore, the need for flexibility within an organization by examining market and manufacturing process related factors. Each factor is further examined to find out relevant flexibilities and corresponding methods, tools, and techniques to be used by suggesting proposed manufacturing approaches to organizations. The human factor is suggested as an essential flexibility component as well as a key contributor for selecting, developing, improving and implementing flexibilities in order to succeed in markets that are accelerating and becoming more turbulent.

2.3.3 Types of Manufacturing Flexibility

Manufacturing flexibility can be viewed as a multi-dimensional concept rather than as an independent variable that can be defined and measured in isolation. It is a product of a number of important enablers such as corporate culture, management structure, process technology, facility layout, and information systems. The development of a generic taxonomy is likely to remain elusive as manufacturing flexibility clearly possesses both a strategic and an operational dimension; it can manifest itself in many forms at various and distinct operational levels in an enterprise. A more positive contribution to the work in this area is the emphasis placed on the relationships which exist between each type of flexibility, underscoring the need to understand the implications of acquiring and implementing manufacturing flexibility from a strategic, as well as from an operational and tactical perspective. Understanding the constituent dimensions of manufacturing flexibility and their interrelationships would be of value to the organizations whose competitive strength depends on flexible manufacturing.
Mandelbaum (1978) defines flexibility as the ability to respond effectively to changing circumstances. Mandelbaum observes that flexibility is used in two different contexts. One relates to situations like regional planning and plant expansion where decisions are made sequentially and without knowing what the future will bring, e.g., how fast the demand for the product of the plant will grow and stated as action flexibility. The other context in which flexibility is used is that in which the system considered is able to operate well in many different circumstances. He called it state flexibility – the capacity to continue functioning effectively despite the change. The system has built in absorbency, robustness or tolerance to change.

Buzacott (1982) defines two types of flexibilities – job flexibility and machine flexibility. Job flexibility is the ability of the system to cope with changes in the jobs to be processed by the system. This can be achieved either at machine level or at system level. At the machine level, it can be achieved by increasing the capabilities of the machine, and at the system level, job flexibility can be achieved by distributing required capability among a variety of machines or work stations, each of which would be specialized to do certain processing tasks. Machine flexibility is the ability of the system to cope with changes and disturbances at the machines and work stations.

Browne et al. (1984) comprehensively and informatively described a set of eight flexibilities in terms of the capability of the firm to manage uncertainty in the dynamic market environment and are reproduced in Table 2.2.

<table>
<thead>
<tr>
<th>Flexibility Type</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Machine</td>
<td>“the ease of making the changes required to produce a given set of part types.”</td>
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<tr>
<td>Process</td>
<td>“the ability to produce a given set of part types, each possibly using different materials, in several ways.”</td>
</tr>
<tr>
<td>Product</td>
<td>“the ability to changeover to produce a new (set of) product(s) very economically and quickly.”</td>
</tr>
<tr>
<td>Routing</td>
<td>“the ability to handle breakdowns and to continue producing the given set of part types.”</td>
</tr>
<tr>
<td>Volume</td>
<td>“the ability to operate an FMS profitably at different production volumes.”</td>
</tr>
<tr>
<td>Expansion</td>
<td>“the capability of building a system and expanding it as needed, easily and modularly.”</td>
</tr>
<tr>
<td>Operation</td>
<td>“the ability to interchange the ordering of several operations for each part type.”</td>
</tr>
<tr>
<td>Production</td>
<td>“the universe of part types that the FMS can produce.”</td>
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</table>

Gustavsson (1984) has examined three different types of flexibilities, namely demand flexibility, machine flexibility, and product flexibility and related them to the anticipated
changes in environment. *Product flexibility* relates to the possible changes in the products. These involve new machinery, systems, and production methods. *Demand flexibility* related to changes in demand which include demand fluctuations and insecurity over a period. He also suggested few guidelines for increasing flexibility in the manufacturing system like use of module, adopting standardization, encompassing large number of alternatives in final operations of a product, and development towards automation.

Frazelle (1986) describes five types of manufacturing flexibility – parts manufacturing flexibility, product mix flexibility, volume flexibility, routing flexibility and design change flexibility. *Parts manufacturing flexibility* helps the system to absorb any changes in product mix, volume, routing, and design quickly and economically. *Product mix flexibility* helps in simultaneous processing of a mix of different parts loosely related to one another by shape or routing. *Volume flexibility* allows the accommodation of shift in volume for a given part. Volume flexibility requires flexible layouts which adapt easily to a change in the number of tools. *Routing flexibility* is the ability of the system to dynamically assign parts to the machines, quickly and economically. *Design change flexibility* permits rapid and inexpensive implementation of engineering design changes for a particular part. A system possesses design change flexibility when the product design, process planning, and manufacturing functions are integrated.

Carter (1986) defines six types of flexibilities in a way that assists in analysis and design. The various types of flexibilities are machine flexibility, routing flexibility, mix flexibility, mix change flexibility, production flexibility and expansion flexibility. Further, Lim (1986) considers five types of flexibilities namely machine flexibility, process flexibility, product flexibility, routing flexibility and volume flexibility. He has identified strategic and operational objectives for implementing flexibility and also validated certain views on relationship between management objectives and manufacturing flexibility.

Son and Park (1987) have identified four types of flexibility measures for a given production period and quantified each measure on the basis of a related cost. The four types are: product flexibility, process flexibility, demand flexibility and equipment flexibility. Besides these four partial flexibility measures, a *total flexibility* measure is also defined as a global measure of the opportunity of a manufacturing system to add value to the products. The total flexibility is the ratio of the physical output of the manufacturing system to the sum of the four costs mentioned in the partial measures.
Azzone and Bertele (1989) have classified flexibility into six elementary types—routing flexibility, process flexibility, product flexibility, production flexibility, volume flexibility and expansion flexibility. Further, they have introduced a method which helps in evaluating the economic impact of a manufacturing system’s flexibility. Slack (1989) suggests that four types and two dimensions of manufacturing flexibility can be identified at the system’s level: new product flexibility (related to the system’s ability to introduce different products or modify existing ones), mix flexibility (related to the system’s ability to manufacture a broad range of products within a given period of time), volume flexibility (related to the system’s ability to change its aggregated level of output), and delivery flexibility (related to the ability of the system to change delivery dates). Slack also defines two manufacturing flexibility dimensions: range flexibility—the total envelope of capability or range of states which the operations system is capable to achieve, and response flexibility—the ease, in terms of cost or time, with which changes can be made within the capability envelope.

Sethi & Sethi (1990) noted the existence of at least 50 different terms for the various types of flexibility referred to in the literature; definitions, which “are not always precise and are, at times even for identical terms, not in agreement with one another”. Sethi & Sethi further attempt to “facilitate an overview of the various types of flexibility and their interrelationships”. A set of flexibility types is subsequently developed which, like Gupta & Goyal (1989) follows that provided by Browne et al. (1984). The original eight flexibility types are expanded to eleven, which in the authors’ words “deviate from their view occasionally”. Suggested methods of measurement are also developed for specific types of flexibilities and their interrelationships.

The eleven types of flexibility are: machine, material handling, operation, process, product, routing, volume, expansion, program, production and market flexibility. Of these, material handling, program and market flexibility are wholly new additions to the taxonomy of Browne et al. (Table 2.3). The first three of the eleven, are considered as basic system components, whilst the remaining eight apply to the manufacturing system as a whole. The work of Sethi & Sethi places manufacturing flexibility firmly in the wider context of the organization and the business environment and therefore the strategic flexibility arena, emphasizing the role these broader issues play in the pursuance of flexibility. It also acknowledges that “sophisticated computer and information technology and a flexible organizational structure underlie” each of the flexibility types.
Table 2.3 Flexibility types additional to Browne’s original taxonomy, (Sethi & Sethi, 1990)

<table>
<thead>
<tr>
<th>Flexibility Type</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Material</td>
<td>“flexibility of a material handling system is its ability to move different part types efficiently for proper positioning and processing through the manufacturing facility it serves.”</td>
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<tr>
<td>Program</td>
<td>“the ability of the system to run virtually unattended for a long enough period.”</td>
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<tr>
<td>Market</td>
<td>“the ease with which the manufacturing system can adapt to a changing market environment.”</td>
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Chen *et al.* (1992) classify flexibility into two broad categories – marketing based flexibility and manufacturing based flexibility. *Marketing based flexibility*, which consists of product flexibility, volume flexibility, mix flexibility and expansion flexibility, is concerned with the capability to cope with dynamic market changes. *Manufacturing based flexibility*, on the other hand, includes machine flexibility, material handling flexibility, process flexibility, labor flexibility, routing flexibility and programming flexibility. It deals with flexibility inherent with the manufacturing resources and management that provide or support the desired level or marketing based flexibility.

Hyun and Ahn (1992) define *volume flexibility* from an environment-associated view as the ability to accelerate production very quickly and juggle the orders to meet demand for unusually rapid delivery and to operate profitably at different production volumes. Additionally, Hyun and Ahn further described the *strategic flexibility* as the ability of firms “to reposition themselves in a market, change their game plans, or dismantle their current strategies when the customers they serve are no longer as attractive as they once were.”

According to Corbett (1992) *delivery flexibility* is introduced to support dependable and fast delivery in the face of competition. Delivery flexibility includes the ability to respond to other customer orders, to change product mix to suit availability of materials or labour, or to accommodate special orders for favored customers by reallocating capacity.

Pyoun and Choi (1994) have developed the concept of potential flexibility and realizable flexibility. When the flexibility inherent in a manufacturing system is analyzed from the system manufacturer’s point of view, before it is implemented and operated by the user, it is referred as *potential flexibility*. The user will operate the manufacturing systems using both potential flexibility and their engineering and management capability to realize the given manufacturing strategy and to fulfill specified market demand. When flexibility is analyzed which will be realized following such operation from the user’s points of view, it is referred as *realizable flexibility*. Potential flexibility is further classified into four
elements – incremental investment flexibility, tooling flexibility, interchange flexibility and software flexibility. Realizable flexibility is classified into three groups – investment policy group, internal control group and marketing adaptation group.

Suarez et al. (1996) define *volume flexibility* as the ability to vary production volumes without any detrimental effect on efficiency and quality. New (1996) states that “volume flexibility of a plant is concerned with the range over which the output volume of the plant can be varied on a daily/weekly/monthly/yearly basis and with the impact such variability in output has on the unit cost characteristics of the plant”.

Lau (1996) describes the *strategic flexibility* as firm’s ability to respond to uncertainties by adjusting its objectives with the support of its superior knowledge and capabilities. The latter consist of people, processes, products, and integrated systems. Strategic flexibility allows a firm to support the development of future manufacturing strategies, and these enable it to react swiftly to the changing nature of internal and environmental conditions and supported through the use of advanced information technologies. Not only, but world-class manufacturing firms also can influence market demand, creating uncertainties or customer expectations that competitors cannot deal with. Further, rapid advances in information technology (IT) are having a major impact on the management of supply chains. To achieve the required supply chain flexibility types requires implementation of sophisticated information technologies such as an electronic data interchange (EDI) and internet-based technology applications such as supply chain management (SCM), customer relationship management (CRM), and enterprise resource planning (ERP).

D’Souza and Williams (2000) identify two elements to define *volume flexibility* – range and mobility. The range element of volume flexibility is defined as the range of output volumes at which the firm can run profitably. The mobility element of volume flexibility is defined as the time required to increase or decrease output and the cost of increasing or decreasing volume of output.

Narasimhan and Das (2000) in their study portrayed a strategic aspect of delivery flexibility in support to the market and new product flexibility firstly described by various authors as discussed earlier. *Delivery flexibility* facilitates the rapid delivery of innovative, customized products and services for new market creation. It enables manufacturing to be recognized as a key contributor and shaper of corporate strategy.
Dangayach and Deshmukh (2001) have classified manufacturing flexibility into two broad types’ i.e. structural flexibility and infrastructural flexibility. Structural flexibility (such as related to capacity, facility and technology) deals with issues that set the process and technology for operations. Infrastructural flexibility (such as related to human resource policies, quality policies, organizational culture, environmental issues etc.) provides the necessary support to the operation function.

Shi and Daniel (2003) reviewed the existing literature on manufacturing flexibility, and extract from it guiding principles for creating and managing e-business flexibility. They found flexibility an abstraction in the e-business domain and an effective means by which an e-business can hedge against uncertainty in a swiftly changing environment. Systems, applications, and business processes—in short, the entire environment supporting e-business—must seamlessly adapt to changes without costly and time-consuming infrastructure overhauls.

Pagell and Krause (2004) re-explored the relationship between different dimensions of manufacturing flexibility viz. delivery, volume, mix, changeover and modification and the external environment and find no support for the proposition that firms that respond to increased uncertainty with increased flexibility will experience increased performance. They described delivery flexibility in their study as the ability to effectively respond to changes in planned delivery dates, volume flexibility as the ability to effectively increase or decrease aggregate production in response to customers, mix flexibility as the ability of a manufacturing system to effectively produce a wide variety of different products, changeover flexibility as the ability of a manufacturing system to effectively handle additions and subtractions to the product mix over time and modification flexibility as the ability of a manufacturing system to effectively implement minor changes in current products that result from corrective actions or changing customer requirements.

The multi-dimensional nature of manufacturing flexibility indicates that supply chain organizations may require different types and levels of flexibility based on their strategic objectives. As a result, manufacturing flexibility is not generic and cannot simply be treated as a commodity that could be bought off-the-shelf and immediately applied; rather, it should be justified, planned, and managed carefully in order for its potential benefits to be fully realized. Stevenson and Spring (2007) presents a timely review of the available literature and provides a more complete definition of flexibility in the context of supply chains. They describe flexibility simply as a reactive means to cope with
uncertainty. It is argued that supply chain flexibility has emerged from the manufacturing flexibility literature and hence to date is largely confined to a manufacturing context (neglecting the role of services). Empirical research often takes the form of a cross-sectional postal questionnaire conducted at the firm-level that fails to explore the inter-organizational components of supply chain flexibility.

2.3.4 Defining Research Constructs

It is proposed to focus on three dimensions of manufacturing flexibility - volume flexibility, modification flexibility and delivery flexibility in the study and defined in light of the existing literature.

Volume flexibility

Volume flexibility is the ability of the organization to operate at various batch sizes and/or at different production output levels economically and effectively. It demonstrates the competitive potential of the firm to increase production volume to meet rising demand and to keep inventory low as demand falls (Gerwin, 1993; Sethi and Sethi, 1990). It is widely discussed in economics literature and assessed by the cost curve (Carlson, 1989). The main strategic purpose of volume flexibility is to help cope with cumulative demand ambiguity. Volume flexibility permits the firm to adjust production upwards and downwards within wide limits. In terms of range, mobility and uniformity, volume flexibility is “the extent of change and the degree of fluctuation in aggregate output level, which the system can accommodate without incurring high transition penalties or large changes in performance outcomes”. Volume flexibility describes the ability of manufacturing system to operate economically over a range of aggregate output volumes. Recessions and market booms highlight the need for volume flexibilities. Marketing strategies such as discounting and promotions create volume fluctuations, which demand a volume flexible system. The operational definition of volume flexibility for this research is, therefore, takes into consideration the competitive criteria of a plant.

“Volume flexibility is defined as the capability which a manufacturing system has to vary its output level for a given product mix, within a given time period without any unacceptable effect on cost and other competitive criteria of the plant.”

Some researchers, for example, Cox (1989), New (1996) and Oke (2003) have argued that, in competitive terms, volume and mix flexibility are the two most important manufacturing flexibility types.
Modification flexibility

Modification flexibility (Gerwin, 1993) refers to the ease of producing minor alterations in product design to meet customization or differentiation requests. Such design modifications are often undertaken in response to product tests and to resurrect declining sales. Modification flexibility is useful for product and market differentiation efforts and overall market share growth. These plant level competencies are often the basis of medium term tactical responses to changes in market requirements. Modification flexibility can also be defined as the number and heterogeneity of product modification, which are accomplished without incurring high transition penalties or large changes in performance outcomes (Koste and Malhotra, 1999).

Modification flexibility defined in context to the present study is: “Modification flexibility is defined as the capability of the manufacturing system to meet customization requests for minor design/feature product changes”.

Delivery flexibility

New product flexibilities is a powerful, core competence that enables the organization to reduce product life cycles, increase market share and create uncertainty for the competition. Delivery flexibility is supported by new product flexibility and enables the rapid delivery of innovative, customized products and services for new market creation (Narasimhan and Das, 2000). Delivery flexibility is introduced to support dependable and fast delivery in the face of competition (Corbett, 1992). It enables manufacturing to be recognized as a key contributor and shaper of corporate strategy.

Operational definition of delivery flexibility at strategic level in context to the present study is defined as: “Delivery flexibility is defined as the ability of manufacturing system to respond to or influence market changes and enables the rapid delivery of innovative, customized products and services for new market creation”.

2.3.5 The Nature of Manufacturing Flexibility

Manufacturing flexibility can be classified variously according to how it is perceived (internal, external), and over what time scale it is considered (long term, short term), etc. However, irrespective of the level or perspective from which it is viewed, each type or “dimension” of flexibility can be divided into a number of smaller elemental characteristics that describe its bounds. Typical of these dimensions is the range of states
that can be achieved, the ability to change through the available range and the uniformity of performance across the range of available states. In addition to the efforts that have been directed at identifying and defining the components of flexibility, attempts have also been made to characterize the concept and nature of flexibility.

Yilmaz and Davis (1987) have examined manufacturing flexibility through different dimensions of time. They define flexibility by three attributes – flexibility at times, flexibility after a time and flexibility over time. ‘Flexibility at times’ refers to the ability of the manufacturing system to cope with unpredictable and sporadic changes that are usually interior to the system for example, machine breakdowns. Machine flexibility and routing flexibility can be related to ‘flexibility at times’. ‘Flexibility after a time’ refers to the ability of the system to handle foreseeable short term changes in the environment, for example, a variation in production volume due to demand fluctuation. Product, process and process sequence flexibilities can be related to ‘flexibility after a time’. ‘Flexibility over time’ refers to the ability of the system to handle known, long term, and sometimes permanent changes, for example, a change in the system configuration due to the installation of new equipment. Volume, expansion and production flexibilities can be related to ‘flexibility over time’.

Barad and Sipper (1988) have segmented various flexibilities under the ‘short to medium term’ and ‘long term’ categories. Various flexibility categorized under ‘short to medium term’ are machine set up flexibility, process flexibility, transfer flexibility, volume flexibility, routing flexibility and operation flexibility. Product flexibility, production flexibility and expansion flexibility have been considered as long term flexibilities.

Carlson (1989) goes on to distinguish three types of flexibility: operational (short-term), tactical (medium-term) and strategic (long-term). Operational flexibility corresponds to built-in procedures that permit a large range of responses to operational variables (e.g. sequencing, scheduling). The operational level considers the problem of efficiently utilizing flexibility in day-to-day operations, to ultimately capture the potential benefits from investments in increased flexibility. Tactical flexibility refers to the embodiment in technological and organizational routines of responses in how to deal with quantitative and qualitative changes in rates of production, product mix over the course of a business cycle, etc. At the tactical level, processes for creating and developing flexibility are constructed. The objective at this level is to determine the extent, measurement, and expected returns of flexibility functions. Strategic flexibility relates to how the firm is
positioning itself with respect to future challenges and opportunities. At the strategic level, a firm determines an appropriate level of investment in flexibility, as well as the types of flexibility in which to invest. Decisions at this level consider the dynamic business environment in which the firm operates in order to choose a role for flexibility that reflects the firm's strategic long-term needs.

Carlson’s distinctions between the three classes of flexibility attempts to capture the notion of flexibility as a portfolio of routines evoked in relation to foreseeable environmental variations as well as a capability, always conjectural and fallible, to supply innovative responses to novel problems. Carlson’s strategic flexibility appears to stretch the notion of flexibility beyond the scope of most accepted definitions. Carlson regards the barriers to operational and tactical flexibility as being embodied in physical assets and the way they are deployed whilst the barriers to strategic flexibility are deemed to “… be more likely to be of a mental or organizational nature”.

Rao and Mohanty (1991) have reviewed the literature on flexibility and tried to explore inter-relationships between different types of flexibilities. They provide a hierarchical approach to the concept of flexibility for assessing the broad flexibility needs of the organization. For this, flexibilities have been classified as strategic, tactical, and operational flexibility. They have also suggested a framework for measuring flexibility.

Gerwin (1993) exploits the notion that hierarchical taxonomies may encourage the proliferation of flexibility types, to argue for the development of a taxonomy that can be applied at different hierarchical levels. By virtue of its universality, he speculates, a taxonomy that can be applied at the machine level, the cell level, the plant level, etc. may reduce the need for context specific flexibility types. The proposed taxonomy, mix, changeover, modification, volume, rerouting and material flexibility is derived from the identification of the strategies used to accommodate specific uncertainties.

D’Souza and Williams (2000) define and test four dimensions of flexibility, with volume and variety flexibility categorized as externally driven dimensions and process and materials handling flexibility classified as internally driven dimension. These attempts at categorizing flexibility can be seen as distinguishing between the ability to change output either qualitatively (e.g. make different products) or quantitatively (i.e. make more or less).
2.3.6 Categorization of Manufacturing Flexibility

Bessant and Heywood (1986) stress that achieving benefits of flexibility in practice depends on successfully resolving a number of issues, like technical, economical, and organizational issues. They have suggested a number of measures which the company must adapt while incorporating more flexibility.

Gupta and Goyal (1989) have attempted to categorize various flexibility measures into six types of approaches: economic consequence based approach, performance based approach, multi-dimensional approach, petri-net approach, information theoretic approach, and decision theoretic approach.

A useful attempt at “clarifying and unifying the definitions of manufacturing flexibility” is provided by Hyun & Ahn, (1992) who construct a framework using the various research studies of manufacturing flexibility. In this framework, each study is classified in one of three groups as either, system, environment-associated or decision-hierarchical, according to the perspective of the research.

From the system view, system flexibility is the sum of the flexibilities of the system’s functions. Similarly, a functional flexibility, such as manufacturing, is composed of component level flexibilities which are further classified as (i) “software”, e.g. control flexibility, worker flexibility, and (ii) “hardware”, e.g. machine flexibility and routing flexibility. The system view emphasizes the need to co-ordinate the management and development of all functional flexibilities to achieve total system flexibility. A similar holistic view is adopted with the management and development of the function’s component flexibilities.

The environment-associated or traditional view of flexibility is characterized by the notion of internal and external environments and the interaction of the component flexibilities with the environmental uncertainties, i.e. expansion flexibility, product, mix, volume and program flexibility. These flexibilities are further classified as being either “static”, usually embodied in process technology, or “dynamic”, usually embodied in the organizational culture.

The third group, decision-hierarchical comprises of long term (strategic), midterm (tactical) and short term (operational) flexibility. These are defined respectively as (i) the ability of a system to respond to: market changes, changes in strategy, new product introduction and basic design changes, (ii) the ability to operate at varying rates, to handle a variety of parts of known basic design, to accept random, minor changes and to convert
the plant for alternative use, and (iii) the ability to reset and readjust between known production tasks, to permit a high degree of variation in sequencing and scheduling, etc. Flexibility types categorized under the groups are classified as being either dynamic or static in nature.

Chambers (1992) considers flexibility within manufacturing strategy for manufacturing strategy development. Product flexibility and volume flexibility, the volume being either aggregate or specified by the mix, are relative to the first two stages (definition of the firm’s aims and the marketing ones); those types of flexibility which have a direct impact on price, quality and service performances (Chambers mentions set-up, quality and delivery flexibility- delivery flexibility is required when the customer’s lead time is inferior to production lead time or when the customer changes the amount or times of the orders) are relative to the third stage (definition of the qualifying aims with respect to the competitors); process and planning flexibility are relative to the fourth and fifth steps (choice of the processes and infrastructures).

De Toni and Tonchia (1998) made an attempt to classify the vast literature regarding manufacturing flexibility; the aim which was to contribute to the conceptual systemization of the debate, whose richness plays witness of the abundance of themes and the difficulty of obtaining a unitary and univocal framework. The literature on manufacturing flexibility was analyzed according to a scheme which considers six different aspects: (1) definition of flexibility, (2) request for flexibility, (3) classification in dimensions of flexibility (the authors group the various classifications proposed according to different logics: horizontal, vertical, temporal, by the object of the variation, mixed), (4) measurement of flexibility, (5) choices for flexibility, (6) interpretation of flexibility.

Oke (2005) proposed a framework for analyzing flexibility in manufacturing companies. Various enablers of flexibility were identified and further classified into three broad sources of flexibility namely fundamental enablers, indirect enablers and generic enablers as well as flexibility avoidance strategies referred to as flexibility evaders. The implication is that a mix of flexibility solutions rather than a single solution may be the most appropriate way for delivering flexibility in an organization. However, the drivers of the need for flexibility have to be correctly identified in order to determine the best solutions for delivering system flexibility.


2.3.7 Taxonomy of Manufacturing Flexibility

A literature based, hierarchical taxonomy of manufacturing flexibilities that integrates the different perspective has been developed in light of the available literature and presented in Table 2.4. At the lowest level in the hierarchy are operational flexibilities and its components- equipment, material, routing, material handling and programme flexibilities (Browne et al., 1984; Carter, 1986; Gerwin, 1987; Gerwin, 1993; Sethi and Sethi, 1990; Gupta and Somers, 1992) - manifested in machine or shop floor operations on a regular basis. Operational flexibility corresponds to built-in procedures that permit a large range of responses to operational variables including sequencing and scheduling.

Tactical flexibility refers to the embodiment in technological and organizational routines of responses in how to deal with quantitative and qualitative changes in rates of production, product mix over the course of a business cycle, etc. These operational capabilities impact the development of plant level (one level higher in the hierarchy) and include flexibilities such as mix, volume and modification flexibilities (Browne et al., 1984; Gerwin, 1993; Slack, 1983; Sethi and Sethi, 1990; Koste and Malhotra, 1999).

At the highest level are the strategic flexibilities, consisting of new product, market, delivery flexibility and sourcing flexibility (Browne et al., 1984; Sethi and Sethi, 1990; Gerwin, 1993; Narasimhan and Das, 2000; Pagell and Krause, 2004; Kumar et al., 2006). While tactical flexibilities relate to internal manufacturing capabilities, strategic flexibilities are external in application and relates to how the organization is positioning itself with respect to future challenges and opportunities. These flexibilities centre on customer and market issues, and can change the very basis of competition in an organization (Chung and Chen, 1990).

The taxonomy developed above is useful for two reasons. First, it provides a basis for evaluating the relative managerial importance of different flexibility dimensions. Managerial perceptions of manufacturing flexibility differ depending on functional affiliation. Slack (1990) notes that manufacturing managers identify with five types of flexibilities- new product flexibility, modification flexibility, mix flexibility, volume flexibility, and delivery flexibility. Process and industrial engineers focus on mix flexibility, product engineer on product and modification flexibility. Purchasing, marketing and plant level management are generally interested in all five types of flexibilities (Slack, 1990). Second, the taxonomy helps to understand and define potential
roles for purchasing in pursuit of manufacturing flexibilities. It is reasonable to speculate that sourcing affects some aspects of manufacturing flexibilities more than others.

Table 2.4 Taxonomy of manufacturing flexibilities

<table>
<thead>
<tr>
<th>Level</th>
<th>Manufacturing flexibility Dimensions</th>
<th>Description</th>
<th>Supporting Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Flexibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Machine/shop level)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment flexibility</td>
<td></td>
<td>The ability of a machine to switch among different types of operations without prohibitive effort</td>
<td>Browne et al. 1984; Carter 1986</td>
</tr>
<tr>
<td>Material flexibility</td>
<td></td>
<td>The ability of equipment to handle variations in key dimensional and metallurgical properties of inputs.</td>
<td>Gerwin 1987, 1993</td>
</tr>
<tr>
<td>Routing flexibility</td>
<td></td>
<td>The ability to vary machine visitation sequences for processing a part</td>
<td>Browne et al. 1984; Gerwin 1987, 1993</td>
</tr>
<tr>
<td>Material handling flexibility</td>
<td></td>
<td>The ability of the material handling system to move material through the plant effectively</td>
<td>Sethi and Sethi 1990; Gupta and Somers, 1992</td>
</tr>
<tr>
<td>Program flexibility</td>
<td></td>
<td>The ability of equipment to run unattended for long periods of time</td>
<td>Sethi and Sethi 1990; Gupta and Somers, 1992</td>
</tr>
<tr>
<td>Process flexibility</td>
<td></td>
<td>Ability of manufacturing system to adapt to changes in production process including to change sequence of steps through which product must progress</td>
<td>Gerwin 1987; Sethi and Sethi 1990 and Sarker et al. 1994</td>
</tr>
<tr>
<td>Tactical Flexibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Plant level)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mix flexibility</td>
<td></td>
<td>The ability of a manufacturing system to switch between different products in the product mix</td>
<td>Browne et al. 1984; Gerwin 1993; Gupta and Somers, 1996</td>
</tr>
<tr>
<td>Volume flexibility</td>
<td></td>
<td>The ability of the manufacturing system to vary aggregate production volume economically</td>
<td>Slack, 1983; Browne et al. 1984; Sethi and Sethi 1990; Pagell and Krause, 2004</td>
</tr>
<tr>
<td>Modification flexibility</td>
<td></td>
<td>The ability of the manufacturing process to customize products through minor design modifications without incurring high transition penalties or large changes in performance outcomes.</td>
<td>Gerwin 1993, Koste and Malhotra, 1999</td>
</tr>
<tr>
<td>Strategic Flexibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Organizational level)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New product flexibility</td>
<td></td>
<td>The ability of the manufacturing system to introduce and manufacture new parts and products</td>
<td>Browne et al. 1984; Gerwin 1987, 1993; Taymaz, 1989; Gupta and Somers, 1996</td>
</tr>
<tr>
<td>Market flexibility</td>
<td></td>
<td>The ability of the manufacturing system to rapidly respond to or influence market changes</td>
<td>Sethi and Sethi 1990; Gerwin 1993</td>
</tr>
<tr>
<td>Delivery flexibility</td>
<td></td>
<td>The ability of manufacturing system to enables the rapid delivery of innovative, customized products and services for new market creation</td>
<td>Narasimhan and Das, 2000; Pagell and Krause, 2004</td>
</tr>
<tr>
<td>Sourcing flexibility</td>
<td></td>
<td>The ability of the supply chain partners to control the supply levels (increasing or decreasing) economically and with no additional time to meet customer demand</td>
<td>Kumar et al., 2006</td>
</tr>
</tbody>
</table>
Slack (1983) presents a flexibility hierarchy that relates organization performance to two flexibility levels; the system and resource levels. System flexibility corresponds to the manufacturing tasks in terms of product, mix, volume and delivery flexibility. Resource flexibility in turn refers to different groups of flexibility elements that enable manufacturing’s tasks. Included in these perspectives are structural factors such as technology and labour, and infrastructure factors such as supply base and production control. Both factors are considered fundamental to the realization of manufacturing flexibility (Slack 1990, Sethi and Sethi 1990). However, the scope of this work has been limited to the advanced manufacturing technology and the use of specific/different sourcing practices with different aspects of manufacturing flexibilities.

2.3.8 Management of Manufacturing Flexibility

Trends and thoughts in various disciplines, including management of manufacturing flexibility and technologies, have undergone a metamorphosis, especially during the last few decades. Evolution of knowledge in management and production technologies is synonymous with that in the natural sciences and Sushil (1997) has described this phenomenon characterized by ever shifting paradigms.

Past research has addressed the issue of manufacturing flexibility achievement as essentially one of obtaining and successfully implementing advanced manufacturing systems (Sethi and Sethi, 1990). Divergent opinions have been expressed about the key success factors for implementation of such manufacturing systems, primarily involving appropriate strategic and organizational changes that should accompany new technologies (Upton, 1995, 1998, Dangayach and Deshmukh, 2001). Integration of technology, human resource, marketing and top management supports are considered vital to successful implementation of advanced technologies (Gyan-Baffour, 1994). Gerwin (1993) suggests that advanced manufacturing technology represents just one way of delivering flexibility. Sourcing is mentioned as an alternative strategy for coping with demand uncertainties. Other coping strategies include demand management through effective manufacturing – marketing schedule sharing, improved forecasting efficiencies and other demand influencing programme (McCutcheon et al., 1994). Furthermore, there is a growing recognition of the contribution of sourcing to the attainment of manufacturing flexibility capabilities. The need for sourcing to be supportive of corporate competitive priorities has been stressed by Watts et al. (1992) in their framework linking sourcing practices to corporate competitive priorities. Preceding studies have found varied relationships
between sourcing and different manufacturing flexibilities (Suarez et al. 1996, Narasimhan and Das, 1999 and 2000). Koste and Malhotra (1999) also stressed upon the investigation of presence or absence of flexibility in supply chains, and its relationship with performance and flexibility. Supply chain structures can range from segmented, with minimal interaction among the supply chain members, to integrated, with extensive interaction among the supply chain partners (Krajewski & Ritzman, 1998, Stevenson and Spring, 2007). In addition, the competitive priorities of the supply chain may impact flexibility. Efficient supply chains may emphasize certain flexibility dimensions, while responsive supply chains focus on others. An understanding of these differences, if any, would enhance the management of such supply chains.

Lau (1999) examined the relationship between manufacturing flexibility and its five infrastructural scales, which include workforce autonomy, communication, interdepartmental relationships, supplier flexibility and technology. The results suggested that all infrastructural scales, except workforce autonomy, have a direct and positive effect on a firm's manufacturing flexibility.

Narasimhan and Das (2000) investigate the contribution of sourcing practices to manufacturing flexibility and conclude that supplier involvement in matters such as product design and responsiveness to delivery changes have positive impacts on certain types of flexibility. Narasimhan and Das showed that firms seeking manufacturing cost reduction in an agile environment can benefit from the use of modification flexibility.

The paradigm of manufacturing flexibility has been extended to technology management by Wadhwa and Rao (2000). The potential for design flexibility and its judicious integration with the manufacturing flexibility has been discussed. A conceptual framework involving a dynamic control of structural, process and resource flexibility has been presented and its implications for the Indian context have been discussed. A judicious use of information technology has been suggested to benefit from design flexibility. Das (2001) suggest that different manufacturing priorities can be facilitated through the development of specific manufacturing flexibilities. It also indicates that these manufacturing flexibilities can be acquired through the development of purchasing competence in a firm.

Jack and Raturi (2002) uses three in-depth case studies to establish the drivers and sources of volume flexibility and found that that there were several avenues for developing a volume flexible response and that deployment of these tactics is dependent
on the availability of resources and systems. Critical finding of the study was that short- and long-term sources of volume flexibility have a positive, albeit differential, impact on a firm’s performance.

Chang et al. (2003) reviews the manufacturing flexibility practice in small and medium sized firms in Taiwan, and investigated the effect of manufacturing flexibility on business performance under three different business strategies. The premise was that flexibility is multi-dimensional, and companies should select and develop types of flexibility consistent with their business strategy and found that no one specific type of manufacturing flexibility is beneficial under all circumstances. Firms should invest resources and time to develop manufacturing flexibility to fit into their business strategies. Chang also learned that small/medium sized firms could still develop new product flexibility effectively, even with their limited resources through outsourcing all R&D projects to government-supported R&D institutes and/or universities, including new product design, pilot test and process design and teaming up with another firm to establish a long-term contract with suppliers, which makes it easier to adjust production levels from the aspect of material acquisition.

Zhang et al. (2003) describes manufacturing flexibility as an integral part of value chain flexibility and discusses its key sub-dimensions. It provides theoretical justification for a research model that relates flexible manufacturing competencies, volume flexibility, mix flexibility, and customer satisfaction. Based on the extensive literature review, the concept and sub-dimensions of manufacturing flexibility have been defined and clarified including three distinctive attributes: range, mobility, and uniformity.

Haleem (2004) evaluated the buyer supplier relations for manufacturing and service industries in North India and established a concern for long-term relationship with less number of high quality suppliers. Narasimhan et al. (2004) presents a conceptual model that introduces two new constructs: flexibility competence and execution competence as distinct from manufacturing flexibility. Based on the proposed conceptual model and a multistage data envelopment analysis (MDEA) of empirical data, the roles of flexibility and execution competencies in determining performance were examined and found that some firms are more effective than others in exploiting investments in strategic sourcing initiatives to develop manufacturing flexibilities. Thus, lending credibility to the new construct referred to as flexibility competence. They also conclude that some firms are more effective than others in converting manufacturing flexibilities into tangible firm-
level performance, suggesting that execution competence is an important construct that needs attention.

Chang et al. (2005) have investigated the effects of manufacturing proactiveness dimensions (manufacturing involvement, commitment to manufacturing technology advancements and multi-skilled workforce developments, and manufacturing's integration with marketing and design functions) on three types of manufacturing flexibility (new product, volume, and product mix) and found that manufacturing involvement, multi-skilled workforce developments, and manufacturing/design integration have significant positive effects on new product flexibility. Statistical results indicated that manufacturing technology advancements, multi-skilled workforce developments, and manufacturing/design integration lead to better product mix flexibility. In addition, manufacturing involvement, manufacturing technology advancements, and manufacturing/marketing collaboration are determinants of volume flexibility. This research provides deeper insights regarding the impact of manufacturing flexibility upon the proactiveness programs.

Bhardwaj et al. (2006) focuses on the partnership between Indian automotive vendors and vehicle manufacturers for product design activity through structured questionnaire and found low involvement of vendors for this activity and a lot of variation with respect to this activity for different clusters. Gupta et al. (2006) further analyses the current state of supply chain management practices followed by Indian organizations and found that most of the Indian organizations have aligned their supply chain objectives with their business objectives.

Zhang et al. (2006b) introduced the concept of flexible manufacturing competence (FMC) as a measure of a firm’s ability to flexibly deploy resources to support its business strategy. FMC is a set of internal abilities (machine, labor, material handling, and routing flexibilities), which customers cannot see and do not fully appreciate, but firms develop them to create responsive production systems (D’Souza and Williams, 2000; Zhang et al., 2003). FMC is the foundation for creating volume and mix flexibilities, which customers do value. Prahalad and Hamel (1990) contend that firms should focus on building core competencies that create competitive advantage. FMC is the process and infrastructure that support manufacturing flexibility and enables firms to perform at high levels.

Oberoi et al. (2008) explicates the interaction between advanced manufacturing technology (AMT), sourcing practices and manufacturing flexibilities at tactical and
strategic level and assess the first two’s relative impact on different flexibilities. Oberoi reports the findings of an exploratory study of North Indian medium- and large-scale manufacturing organizations, which are in the process of achieving manufacturing flexibilities at various levels by acquiring, developing or utilizing AMT or by the use of specific sourcing practice. The statistical results suggest significant relationships between sourcing practices and manufacturing flexibilities at different levels of manufacturing flexibility. The results also suggest that an organization could deploy specific sourcing practices or AMTs to target specific manufacturing flexibilities in pursuit of agility-based competitive advantages.

2.4 Concept of Technology

Technology means the systematic application of scientific or other organized knowledge to practical task. There are a number of definitions in existence for Engineering Technology, most of which relate to manufacturing and product development industries (Hornbeck, 1999).

Martino (1983) defines technology as the totality of means employed to provide objects necessary for human sustainability and comfort. Technology is also defined as “a body of knowledge, tools and techniques, derived from both science and practical experience, that is used in the development, design, production and application of products, processes, systems and services”(Steensma, 1996).

In a broad sense, technology denotes the broad area of purposeful application of the contents of the physical life and behavioral sciences. It comprises the entire notion of techniques as well as the medical, agricultural, management, and other fields with their total hardware and software contents. Beets (1994) provides a similar definition and states that while science is a general approach to understanding nature, technology is a generic way of providing a functional capacity of doing things.

Technicist definition of technology is offered by Gibson (1976) when he states, “technology is considered to be scientific, engineering and managerial knowledge which makes possible the conception, design development, production, and distribution of goods and services." As a matter of fact, it is a good description only of industrial technology, and thus, a specific example of man's knowledge, which is necessary for the satisfaction of some of his wants.
Gruber and Marquis (1969) defined technology as "the means of capacity to perform a particular activity.” It is derivable from this definition that technology involves process in the sense that it is a human's capability to transform physical objects. This definition on the other hand seems to be so broad as to encompass almost every sphere of human activity. It is also vague in a sense that it does not shed much light on what the ‘means’ or ‘capacity’ for undertaking a given activity might be.

Technology can be defined broadly and also narrowly. An all-embracing definition of technology as discussed is ‘technology means the systematic application of scientific or other organized knowledge to practical task.’

Technology is purposeful application of knowledge developed in various areas. It is clear from the above-mentioned definitions that the concept of technology has been classified by different criteria into categories that include hardware or software; general or firm specific; and alternative, intermediate or appropriate. Technology has the capability of providing significant competitive advantage. However, it cannot be viewed in isolation and an integrated approach in the delivery of a product, process or service to a customer is absolutely necessary if real competitive advantage through customer satisfaction is to be both obtained and sustained (Vandeth, 1991).

Technology addresses the application of scientific and engineering knowledge to the solution of problems while technology management has a broader charter: the integration of technology throughout the organization as a source of sustainable competitive advantage. It has been indicated that the changing dynamics of technology management can be best seen as an evolving technology paradigm for competitive advantage.

2.4.1 New Technology

New technology is a set of productive techniques which offers a significant improvement (whether measured in terms of increased output or savings in costs) over the established technology for a given process in a specific historical context. Also, new technology is a product or process that an organization has not previously used in their operation (Khamba, 2000).

New technology can have different levels of impact depending on their pervasiveness and the structure of organization and society. It impacts organizations, people, products/services and the training functions that support them.
2.4.2 Requirements of New Technology

The nature and structure of a high technology firm is reflected directly from the environment the firm is operating in and the characteristics of the technology it is dealing in (Moharman et al., 1990). The shrinking technology life cycles and market uncertainty are putting pressures on firms for quick commercialization of innovations. This presses the organization from two opposite sides. On the one hand, it requires a firm to use high technology as tools, and on the other hand, it produces high technology as their products. Certain characteristics of the technology itself have strong bearing on organization of hi-tech firms. Nevis et al. (1995) have emphasized that organizations dealing in hi-tech products must visualize themselves as learning systems if they wish to remain ahead of competitors in global business in terms of better quality, delivery and flexibility.

Analyses of R&D performance focuses on contributions made in enhancing capabilities and quality of existing products and processes, development of products and processes yielding major commercial advantages over competition, and advances in the knowledge to cope up with the future challenges (Gold, 1989). Gold emphasized that R&D should generate three additional kinds of improvements which are reducing or minimizing increase in cost of producing existing products, reducing lags behind competitors’ rapid delivery of innovation in products and processes, and adapting designs and processes to shifts in supply and prices input.

Faced with competition from new technologies and rapid introductions of new products by their competitors, leading companies are beginning to focus on improving technology management, the link between product strategy and product development. It has been reviewed by Anders (1999) that companies can achieve significant R&D performance improvements by implementing the technology management best practices used by leading companies to manage the development and implementation of new technologies.

2.4.3 Technology Adoption

Adoption is simply a firm's awareness of a certain technology's existence and the firm's initial pursuit of that technology (Steensma, 1996). Adoption decision refers to the processes by which a new piece of technology is selected for the organization. While the adoption decision clearly affects implementation, it is composed of different processes and is analytically distinct from implementation (Goodman and Griffith, 1991).

It is evident that firms adopt a new technology when they believe that adoption will result in short term or long term payoff in higher profits. Another major strategic reason can be
their interest in gaining experience with the new technology (Amoako-Gyampah and Maffei, 1989). Thus adoption of strategic technologies that enhance the competitiveness of the firm has become one of the most important responsibilities of manufacturing manager (Dimnik and Johnston, 1993).

The definition of technology adoption, in light of the existing literature for this research is considered as: “adoption decision refers to the processes by which a new piece of technology is selected for the organization to have a short term or long-term payoff in higher profits”.

Determination of the technology market structure with special reference to customer preferences, penetration, technology content and planning for establishing of production is necessary to foster early technology adoption (Akhilesh et al, 1994).

The adoption of technologies which are merely intended to replace older technologies in an existing process can stimulate a complex set of changes. Over time, these changes will force a new look at the ways organizations justify investment in new technologies; encourage close interaction between product and process engineers reinforcing the need for simultaneous design and engineering of products; and force a more process-oriented approach to technology adoption which capture costs, especially environmental costs, and flexibility over the entire production supply chain (Greis, 1995). Narvekar and Jain (2006) have developed a framework to understand technological innovation process by introducing constructs to account for the complexity and the uncertainty in the innovation and technology adoption process.

2.4.4 Advanced Manufacturing Technology

The old production paradigm of mass production has long given way to a new one based upon more flexible and advanced manufacturing technologies (AMT) and organizational arrangements with a different basis for competitiveness. Manufacturing has been evolving over the years as different needs and technologies arise. The customer of the twenty-first century, demands products and services that are fast, right, cheap and easy (Dangayach and Deshmukh, 2001). AMT appeared to represent a perfect marriage between technological potential and the manufacturing challenges. AMT refers to manufacturing process technologies that use computers to store and manipulate data (Dean et al., 1992; Zammuto and O’Connor, 1992). AMT is a term that covers a broad spectrum of computer-controlled automated process technologies. AMT is an umbrella term used to describe a wide range of automation and related technologies, which have emerged
during the past two decades as a consequence of developments in information technology (Bessant, 1991). More specifically, AMT can be described as a group of computer-based technologies, including computer-aided design (CAD), computer numerical control (CNC) machines, direct numerical control (DNC) machines, robotics (RO), flexible manufacturing systems (FMS), automated storage and retrieval system (AS/RS), automated material handling systems (AMHS), automated guided vehicles (AGV), bar coding (BC), rapid prototyping (RP), material requirement planning (MRP), statistical process control (SPC), manufacturing resource planning (MRP II), enterprise resource planning (ERP), activity-based costing (ABC), and office automation (OA) (Beaumont et al., 2002). The overall potential of AMT is great, and several problem issues in manufacturing could be solved through increased use of it. Introduction of new products can occur more frequently through use of computer-aided design and manufacturing (CAD/CAM), since the design lead times may be shortened. FMS and automated materials handling systems reduce set-up times and other interruptions so that products flow more smoothly and faster through the plant. More responsive computer-based systems, such as electronic data interchange (EDI), can react quicker to information fluctuations and result in more accurate production planning and integrated supply chains. Integrated production control systems, such as MRP II and ERP, reduce inventories and raw materials, work-in progress and finished goods. Tighter control and flexible manufacturing smooth flow through plant make the flow more predictable and cut the overall throughput time, allowing accurate delivery performances to be achieved. Improvements in overall quality may be achieved through automated inspection and testing, better production, information and the more accurate delivery performances.

AMTs are used for design, manufacturing or administrative activities. Investment in one or several technologies should be associated with simultaneous investment in supportive mechanisms, such as changed work organization and preventive maintenance policies. An approach that structures the field of AMT and describes the patterns of AMT investment and associated support mechanisms would improve the general understanding of AMTs and could support successful implementation.

The quest for lower operating costs and improved manufacturing flexibility has forced a large number of manufacturing firms to embark on advanced manufacturing technologies (AMTs) projects of various types. AMT include a group of integrated hardware-based
and software-based technologies which, when properly implemented, monitored and evaluated, can improve the operating efficiency and effectiveness of the adopting firms. Koh et al. (2005) examines how and to what extent uncertainty affects SME manufacturers who plan and schedule their production using MRP, MRPII or ERP systems. Kanungo and Savla (2004) related soft technology investments and organizational productivity through an empirical study and found a positive relation. Mora-Monge et al. (2007) investigated the issue of strategic fit between Advanced Manufacturing Technologies (AMT) and its impact on performance in developing countries. Stohr and Zhao (1997) studied the workflow management systems, designed to make work more efficient, integrate heterogeneous application systems, and support inter-organizational processes. Narain et al (2007) reviewed a wide range on literature on the investment justification of AMT. They provided an updated and comprehensive perspective of the issues surrounding the problem of investment justification of AMT and provide some direction for future research. Agrawal et al. (2005) further identified the effect of culture and environmental pressures on the rate of change in the requirements of in-house software professionals. Thakur and Jain (2008) have explored the issues of measurement and comparison of the current state of advanced manufacturing technology (AMT) adoption in India, including important information technology (IT) factors, and, surprisingly, this appears to be the first such attempt. This study finds the top six AMTs currently adopted in India are plant certification, local area network, quality circle, computer aided design, MRP/ERP, and wide area network. Clearly four of these top six are directly in the IT area (LAN, WAN, CAD) or directly dependent on it (MRP/ERP systems), indicating a strong IT adoption rate as well as its underlying supportive role in the overall AMT adoption in India.

2.4.5 AMT Configurations and Taxonomy

AMT is used as a term to describe a variety of technologies that use computers to control or monitor manufacturing processes. It includes computer-aided design/computer-aided manufacturing, computer-aided process planning (CAPP), robotics, group technology, flexible manufacturing systems (FMS), electronic data interchange, office automation, computerized numerical control machines (CNC), automated material handling systems, bar coding, decision support systems, enterprise resource planning systems and many other forms of factory automation and control, that can provide cost efficient flexibility and flow in manufacturing. Several authors have structured the AMT field into three
groups. Kaplinsky (1984), Lei and Goldhar (1991) and Meredith (1987) used the dimensions design, manufacture and integration. A similar definition presented by Adler (1988) has been categorized as:

- **Design:** The dimension of AMT includes computer-assisted drafting, design and engineering. The focus of AMTs is on the design of products and processes.
- **Manufacturing:** Computer-controlled processes in the fabrication/assembly industries; automatic materials handling; automatic storage and retrieval systems. The focus of AMTs is on the actual manufacturing and physical transformation of the products.
- **Administrative:** Computerized accounting, inventory control systems and shop-floor tracking systems. This dimension focuses on tracking operations.

Dangayach and Deshmukh (2005) have reported the role of AMTs in context of developing countries like India. These AMTs are classified into Direct AMT, Indirect AMT, and Administrative AMT. It must be mentioned that this set is by no means an exhaustive set of activities. However, it captures the essence of improvement activities as practiced by Indian companies. Hardware base technologies are termed as Direct AMT. Software-based technologies used for product design and scheduling are termed as Indirect AMT, however, Administrative AMTs are used for integration and simplification of business processes:

- **Direct AMT:** Technology used on the factory floor to cut, join, reshape, transport, store or modify materials, e.g. CNC, DNC, robotics, FMS, AS/RS, AMHS, AGV, RP, etc.
- **Indirect AMT:** Technology used to design products and schedule production, e.g. CAD, MRP, SPC, BC, MRP II, etc.
- **Administrative AMT:** Technology used to give administrative support to the factory and integrate its operations with the rest of the organization, e.g. ERP, ABC, OA, etc.

Boyer *et al.* (1996) identified four homogeneous groups of firms, according to their relative emphasis on design, manufacturing and administrative technologies. One of the groups had low investments in design, manufacturing and administrative technologies. Another distinct group invested heavily in design-related AMTs, but had low investments in both manufacturing and administrative-based technologies. A third group had relatively large investments in most technologies. The last group had highest investments
in all technology types. There were no significant differences between the groups regarding profitability. Hard integration, or technical integration, is another important component of AMT application that tells how well implemented the technologies are. It may be realized through computer-integrated transactions between functions, for example between marketing, engineering, production and maintenance, or between processes, such as CAD data directly linked to Computer-Aided Process Planning (CAPP), CAD data directly controlling Computerized Numerical Control (CNC) machines, robots or Flexible Manufacturing Systems (FMS), parts data from CAD linked to Manufacturing Resource Planning (MRP II) software, production schedules generated by MRP II controlling production equipment, various robots or computer-controlled machines linked to computerized material handling devices, etc.

Johnsson (2000) has developed the empirical advanced manufacturing technology (AMT) taxonomy with three groups from cluster analysis on a survey of Swedish metal-working industries. The first group, "the traditionalists" is characterized by firms of relatively small size with low levels of investments in AMT. "The hard integrators" emphasize computerized transactions between sub-units and processes to a larger extent than the investment in administrative, design and manufacturing technologies. "The high investors" group contains relatively large firms that have invested in most technologies and have computerized their transactions significantly more than both the other groups. The differences between the business and manufacturing strategies of the three groups were not as significant as expected. Delivery differentiation was the most important business strategy for all groups and the relative importance of price was greater only for the traditionalists compared to the other groups. The high investors emphasized all manufacturing capabilities to larger extent than the other groups. These findings indicate that firms with heavy AMT investments are better prepared to compete with complementary capabilities than those with low levels of AMT investments.

2.4.6 Facilitators of AMT’s Adoption

Global competition continues to derive the adoption of AMTs (Gupta et al., 1998). The importance of AMTs is attributed to its efficacy in improving the performance measures, i.e. speed of delivery, cost, quality, reliability, flexibility and dependability. Furthermore, AMT is the nucleus of the factory of the future and is crucial in the competitive battles in many countries all over the world, because of which considerable attention is paid to it by business sectors and academic communities. A variety of aspects persuading the adoption
of wide spectrum of AMTs as discussed by the researcher over a period of time can be categorized under strategic and operational, infrastructural, economic and social issues.

**Strategic and operational issues**

AMT may be used to alter the rules of competition in industries, in effect creating an environment in which the firm has a competitive edge based on its use of AMTs. In this environment the firms can frequently introduce new production processes and products with large numbers of varieties and features. They are, thereby, competing simultaneously along all manufacturing capability dimensions, leading to advantages in terms of speed, low cost and high variety. Work-in-progress and changeover time are becoming shorter through simplified change of tools, dies and product variants. Faster speed can also be gained through integrating design activities and manufacturing. Greater product variety can be derived from flexible and modular production set-up, but also from the use of group technology and flow oriented layouts. Mass customization results from “smarter" production technology, that is tailored to the needs of specific designs and customers. The fact that there is less downtime required to shift between families of products or components can result in greater productivity (Johnsson, 2000).

Sohal and Maguire (1996) have discussed the purpose, pattern and outcomes of investments in advanced manufacturing technologies (AMTs) and explored the motivation for investing in AMTs, the nature and size of investments, speed of implementation and outcomes including benefits and difficulties experienced. They conclude that although firms have made positive investments in a range of sophisticated AMTs, they appear to focus on operational benefits with little, if any, attention to marketing and strategic benefits.

Sohal et al. (2001) have revealed in their study about adoption of AMT by South African manufacturers that around three-quarter of the companies adopting AMT use batch production systems where these manufacturing systems benefit from the flexibility provided by AMT. Many researchers have argued that AMT adoption is more likely to be successful if pursued in conjunction with flexible organizational structure to ensure co-operation among the different organizational entities and systems, and also to ensure that the new technology can indeed provide the benefits desired by the adopting firm (Small and Yasin, 1997; Jonsson, 2000).
AMTs differ from earlier technologies in their capacity to increase organizational flexibility because they are programmable, allowing them to produce a wide array of different parts or products in small volumes by changing software instead of replacing hardware (Zammuto and O'Connor, 1992). Not all AMT necessarily leads to increased flexibility, though, but some is designed to increase speed, sometimes at the expense of flexibility. Another type automates what were previously human operations, for example assembly. The operational role of AMT is often seen as an instrument for achieving economies of scale in small batches (Chen and Small, 1996). For mass production firms, the greater flexibility and speed provided by AMTs could result in economies of scope (Goldhar and Jelinek, 1983). In the marketing role AMTs provide the basis that enables firms to exploit competitive advantages fostered by the technology. Mass production firms are expected to gain a competitive edge through their ability to provide a wider range of products at their usual rates of efficiency. Small batch producers can, on the other hand, enhance their process efficiencies while maintaining or improving product flexibility.

Chen and Small (1996) state further that the strategic role of AMT has been related to improving the firm's ability to cope with environmental uncertainty, but that it has also been viewed as an important factor in the overall improvement of industrial performance.

**Infrastructural issues**

Direct labour with high technical competence and high skill level within the entire organization most likely results in motivated and empowered labour and improved labour/management relations. These infrastructural aspects (e.g. worker empowerment, improvement programmes and organic organizational structure) are especially important for the realization of flexible organizations and AMT success, and there is a growing consensus that organizations with empowered personnel, continuous improvement programmes and organic structures are more likely to realize the full potential of AMT investments (e.g. McLachlin and Piper, 1991; Dean et al., 1992; Saraph and Sebastian, 1992; Maffei and Meredith, 1994; Sun and Gertsen, 1995; Chen et al., 1996; Chen and Small, 1996; Dawson, 1996; Lei et al., 1996; Wong and Ngih, 1997). However, Johnsson (2000) suggest that the relationship between organization structure, infrastructure and AMT benefits ascribed to AMTs are as much an outcome of infrastructure as of AMTs. Zammuto and O'Connor (1992), summarized a study of 50 automobile plants and
showed that plants using traditional technology often outperformed those with AMTs. Bessant and Lamming (1987) estimated that the relative contribution of organizational and human changes to gained benefits during AMT implementation to be between 40 and 70 percent. Several conceptual studies (e.g. Meredith, 1987; Parthasarthy and Sethi, 1992; Twigg et al., 1992) and at least one empirical study (Boyer et al., 1997) have indicated the importance of infrastructural issues for successful implementation of AMTs.

**Economic and social issues**

Although the traditional concept of economies of scale is being replaced by the notion of economies of scope (Goldhar and Jelinek, 1983 and 1985) and FMSs with high process flexibility could provide ways to eliminate this threat (Chen et al., 1992), it has been observed that the current practice of justification of investment in the flexible manufacturing technologies is difficult because there exist only extremely weak methods for analyzing the economic value of flexibility to the manufacturers. The prevailing practice of justifying investments in automated manufacturing is justification by faith.

Roller and Tombak (1993) observe that new manufacturing systems are changing the face of the manufacturing world and have widespread implications for industrial economics. The authors develop and analyze a model of multiple firms’ investment in one of two technologies: a technology dedicated to one product, and a new flexible technology. Ioannou and Sullivan (1999) have developed a two-stage approach for justifying capital investment in material handling systems (MHSs). Small and Yasin (2000) have argued that some researchers have found that unionized firms are less likely to pursue automation because high wage demands deprive them of the necessary capital required to invest in advanced manufacturing technology (AMT).

A major factor worthy of consideration is the likely effect of implementation of FMS on employment levels within the engineering industry. Since one FMS can replace several stand-alone or dedicated machines, it is likely to reduce requirements for machinists and operators. On the other hand, in several of the companies surveyed, implementing FMSs was considered necessity and a failure to do so was likely to herald reduced competitiveness and subsequent company decline (Sharma, 2001). Sharma discovered that the industrial scene has changed drastically during the last decade and it has changed for better. The Indian workers now realize that adopting confrontationist stance is self-defeating. Parhi (2003) has investigated the impact of geography on the adoption of AMTs in the less developed country context.
2.4.7 Benefit of AMT’s

Advanced manufacturing technology is a set of tools that automate and integrate steps in product design, manufacturing, and planning and control (Ettlie and Reifeis, 1987). Design technologies, such as CAD, CAE, and the internet, support product design and engineering (Dahan and Hauser, 2002; Huang and Mak, 1999). They enable firms to work selectively with external designers, suppliers, and customers to compress product development and commercialization. The application of group technology and CAPP has improved process design, which enables firms to make a variety of related parts. Manufacturing technologies, such as CNC, CAM, and AMHS, make production easier and faster. FMS and robotics, which began to attract interest in the early 1970s, allow job shops to reduce batch sizes through short change-over and set-up times (Gunasekaran and Love, 1999; Jonsson, 2000).

Studies conducted in the past two decades showed that the benefits of AMTs are both tangible and intangible and hinge on the type of AMTs and its applications (Schroder and Sohal, 1999; Jonsson, 2000, Sohal et al., 2001; Dangayach and Deshmukh, 2005). They found out AMT adoption brought many benefits to manufacturing firms in the way of an increase in throughput, better management control, overcoming skill deficiencies, reduction of set-up time, accurate materials planning, enhancing company image, obtaining competitive advantage, reduction in costs, expanding product/process flexibility, a decrease in lead-time; reducing “time to market,” better working relationships, improvement in factory utilization, improvement of product quality and improvement in productivity.

Planning and control activities are facilitated by the development of MRP, MRP II, electronic data interchange, and bar coding, which allow firms to manage material flow within the firm and between the firm and its suppliers (Boyer et al., 1996; Cunningham, 1996; Meredith, 1987). Integration technologies such as CIM, local area networking, and enterprise-wide resource planning allow a flow of information and coordinated decision-making between functions within a firm and between firms (Doll and Vonderembse, 1991; Jonsson, 2000). Advanced manufacturing technology can be adapted and customized to a variety of uses through software links and combinations (Ettlie and Reifeis, 1987; Nemetz and Fry, 1988; Parthasarthy and Sethi, 1992).

Lean manufacturing creates a streamlined production system by synergistically implementing a bundle of management practices. This approach grew from the concept of
JIT, and became the doctrine of manufacturers during the late-1980s and the 1990s. Lean manufacturing is characterized by an emphasis on quality, flexibility, and speed (Womack and Jones, 1996). Lean producers employ teams of multi-skilled workers and flexible equipment to achieve small batch production, substantial product variety, and high efficiency (Cooney, 2002; Naylor et al., 1999; White, 1996). Supplier relationships are based on trust and cooperative problem solving (Voss, 1995).

Time-based competition attempts to improve responsiveness by squeezing time from every facet of the value-delivery system (Stalk, 1988). Blackburn (1991) suggests that JIT and its emphasis on manufacturing flexibility was the predecessor to time-based competition. Firms that redesign their processes to compress time can achieve higher productivity, increase market share, reduce risk, and improve customer service (De Toni and Meneghetti, 2000; Schmenner, 1991). Koufteros et al. (1998) develop a set of time-based practices – shop-floor employee involvement, re-engineering set-ups, cellular manufacturing, preventive maintenance, quality improvement efforts, dependable suppliers, and pull production – that improve firm performance.

Total quality management is an integrative approach that strives to achieve customer satisfaction through high quality, value-added products (Deming, 1986). It links work groups so that they can exchange information about variability originating in one group (quality of incoming parts) and how it impacts other groups (production scheduling). Resolving these inter-group problems through improved communication and feedback among work groups can benefit the whole system (Crosby, 1979; Ishikawa, 1985).

2.4.8 Barriers to AMTs

Works cited earlier by Sambasivarao and Deshmukh (1995), Small (1999), Sohal et al. (2001) and Small and Yasin (2003) have identified several barriers that may encounter manufacturing companies to adopt AMT successfully, such as inadequate organizational planning and preparation for the adoption of the AMT, lack of co-ordination with the company’s strategic plan, insufficient knowledge of the organizational pre-requisites for the effective operation of AMTs, opposition by workforce, lack of integration across functions, production management skill deficiencies, opposition by management and obsolescence of technology.
2.5 Concept of Outsourcing

One of the key issues to have emerged for many organizations has been the growing importance of outsourcing. The potential for outsourcing has moved on from those activities that are normally regarded as of peripheral concern to the organization such as cleaning, catering and security, to include critical areas of activity such as design, manufacture, marketing, distribution and information systems with almost the entire value chain open to the use of outside supply (Jennings, 1997). Within organizations, the outsourcing decision is being given more consideration because of its strategic implications. The outsourcing decision can often be a major determinant of profitability making a significant contribution to the financial health of the company (Yoon and Naadimuthu, 1994). Research carried out by Lonsdale and Cox (1997) has revealed that outsourcing decisions are rarely taken within a thoroughly strategic perspective, with many firms adopting a short-term perspective and being motivated primarily by the search for short-term cost reductions. In fact, outsourcing decisions are made most frequently by default, with little consideration for the long-run competitiveness of the organization.

2.5.1 Definitions of Outsourcing

In our present day, increasingly competitive markets, where business cycles are demandingly short, especially in respect to time to solution, time to market, and time to profit, outsourcing has evolved from spot-contracting to relationships where service providers offer products and services that advance the company's strategic business goals (Leisman, 1999) and enhance the provider organization's position in the value chain. There is much debate in management literature defining outsourcing (Gilley and Rasheed, 2000).

Some definitions relate to sourcing activities that were previously conducted in-house. Lei and Hitt (1995) define outsourcing as “reliance on external sources for manufacturing components and other value-adding activities”. Some focus on international sourcing of components, sub-systems and completed products (Bettis et al., 1992; Feenstra and Hanson, 1996). Perry (1997) focused on employment, defining outsourcing as: “another firm’s employees carrying out tasks previously performed by one’s own employees”. Sharpe (1997) defined outsourcing as turning over to a supplier those activities outside the organization’s chosen core competencies. Gilley and Rasheed (2000) provide clarification for the definitional confusion; positioning outsourcing as procuring
something that was either originally sourced internally (i.e. vertical disintegration) or could have been sourced internally notwithstanding the decision to go outside (i.e. make or buy). This includes arrangements and concepts which have been termed: – internal vs external sourcing (Scheuing, 1989); strategic make-or outsource decisions (Virolainen, 1998); contracting out (Gustafsson, 1995); contractorization (Hood, 1997); sub-contracting, purchasing, privatization (Seidenstat, 1996); compulsory competitive tendering, market testing, liberalization (Beaumont, 1991); and make or buy and focus (Knight and Harland, 2000).

Outsourcing has been viewed as a form of predetermined external provision with another enterprise for the delivery of goods and/or services that would previously have been offered in-house (Elfing and Baven, 1994; Domberger, 1998; Kliem, 1999; Finlay and King, 1999). The evolving literature on outsourcing has been concerned with "make-or-buy", or "in source-out source" decisions in relation to the behaviour of enterprises (Loh and Venkatraman, 1992; Elfing and Baven, 1994; Venkatraman and Loh, 1994; Alpar and Saharia, 1995; Carlson, 1989; Hart, 1995) and transaction cost economics (Benko, 1993; Boon and Verberk, 1991).

The operational definition considered in this research for outsourcing is: "Outsourcing is the process of establishing and managing a contractual relationship with an external supplier concerning provision of capacity that has previously been provided in-house".

2.5.2 Key Problems with the Outsourcing Process

Few companies have taken a strategic view of outsourcing decisions, with many companies deciding to buy rather than make for short-term reasons of cost reduction and capacity (Ford et al., 1993). In addition, some organizations may find themselves with an initial position which has been inherited from the past. However, this is likely to have occurred due to a series of short-term decisions with no consideration for the long-term strategic direction of the organization. An outline of three key problems encountered by companies in their efforts to formulate an effective outsourcing decision is presented below.

No formal outsourcing process

Many companies have no firm basis for evaluating the make or buy decision. Lonsdale and Cox (1997) have found that many firms make outsourcing decisions primarily on the basis of reducing headcount and costs. The choice of which parts of the business to
outsource is made by ascertaining what will save most on overhead costs, rather than on what makes the most long-term business sense.

**Limited cost analysis**

Cost analysis of the outsourcing decision involves attempting to measure all the important costs associated with the two alternatives - perform internally or outsource. The alternative that yields the lowest total cost is chosen. There are a number of authors who have put forward mathematical models for the make or buy decision (Mock and Miller, 1970; Raunik and Fisher, 1972; Yoon and Naadimuthu, 1994). Both quantifiable and non-quantifiable factors are used in these analyses. However, other authors such as Morley (1966) argue that cost calculations, in many cases, do not produce a clear marginal decision in either direction. Other more qualitative factors, such as the long-term strategic implications and the workforce reaction to outsourcing for the organization, may have a greater impact on the decision. The problem with basing sourcing decisions primarily on the basis of costs is further exacerbated by the fact that many companies have inadequate costing systems.

**Core business definition**

Outsourcing decisions can impact on flexibility, customer service and the core competencies of the organization. Hamel and Prahalad (1994) postulate that companies who measure competitiveness in terms of price only are inviting the erosion of their core competencies. They define core competence as the combination of individual technologies and production skills that underlie a company's myriad product lines. These embedded skills that give rise to the next generation of competitive products cannot be `rented-in` by outsourcing. Too many companies have unknowingly relinquished their core competencies by cutting internal investment in what they mistakenly thought were `cost centres` in favour of outside suppliers. Outsourcing may provide a shortcut to a more competitive product, but it typically contributes little to build the people embodied skills that are needed to sustain future product leadership. Also, there is evidence to suggest that companies are misusing the term `"core"`.

2.5.3 **Advantages and Disadvantages of Outsourcing**

Outsourcing offers several advantages, such as enabling existing staff to concentrate on core activities on organizational specializations, focusing on achieving key strategic objectives, lowering or stabilizing overhead costs, and thereby gaining cost advantage
over the competition, providing flexibility in response to changing market conditions, and reducing investment in high technology (Kliem, 1999; Quinn 1999). Crucially, outsourcing can provide companies with greater capacity for flexibility, especially in the purchase of rapidly developing new technologies, fashion goods, or the myriad components of complex systems (Carlson, 1989; Harrison, 1994). Small specialized suppliers often offer greater responsiveness through new technologies which have undermined the need for the vertically integrated organization and have also helped achieve economies of scale (Quinn and Hilmer, 1994). A network of suppliers can provide any organization with the ability to adjust the scale and scope of their production capability upward or downward, at a lower cost, to changing demand conditions and at a rapid rate. As such, outsourcing can provide greater flexibility than the vertically integrated organization (Carlson, 1989; Harrison, 1994; Domberger, 1998). Furthermore, outsourcing can decrease the product/process design cycle time, if the client uses multiple best-in-class suppliers, who work simultaneously on individual components of the system, as each supplier can contribute greater depth and sophisticated knowledge in specialized areas and thus offer higher quality inputs than any individual supplier or client (Quinn and Hilmer, 1994). Perhaps the greatest advantage of outsourcing is the full utilization of external suppliers' investments, innovations, and specialized professional capabilities than otherwise would have been the case, which for any one organization would be prohibitively expensive to replicate. However, transferring fixed costs into variable costs by selling assets to an outsourcing vendor is considered an advantage for many organizations. The company receives cash payment and transfers fixed costs into variable overheads (Currie and Willcocks, 1997).

However, there exist several disadvantages to adopting outsourcing strategies. These include becoming dependent on outside suppliers for services, failing to realise the purported hidden cost savings to outsourcing, losing control over critical functions, having to face the prospect of managing relationships that go wrong and lowering the morale of permanent employees (Currie and Willcocks, 1997; Kliem, 1999). Moreover, outsourcing can generate new risks, such as the loss of critical skills or developing the wrong skills, the loss of cross-functional skills, and the loss of control over suppliers (Quinn and Hilmer, 1994; Domberger, 1998). These risks are especially pertinent when the supplier's priorities do not match client needs. Short-term contracts, based on the principle of the lowest winning bid, are claimed to stifle incentives to innovate because
rewards for innovation cannot be captured by the contractor (Domberger, 1998). Furthermore, outsourcing has led to a loss of skills and corporate memory.

2.5.4 The extremes of the sourcing decision

Galbraith (1995) uses the terms “virtual company” (or “networked organization”) and “fully integrated company” to describe the two sourcing extremes. The virtual company is formed when the company decides to outsource all of its business activities – except for the strategic management – to a network of suppliers. This, of course, puts heavy demands and constraints on the management’s ability to establish efficient co-ordination and control mechanisms (e.g. formalization, centralization and socialization) because of the differing operating and cultural environments (Taps, 2000). The virtual company forms a sharp contrast to the fully integrated company which co-ordinates and controls all activities in-house and thus, does not pursue an outsourcing strategy (Figure 2.1). Still, manufacturing companies within this latter category would probably need access to components, accessories and other materials through first and second tier suppliers, considering that companies operating in the industrial segment are rarely self-sufficient.

![Figure 2.1 The extremes of the sourcing decision](image)

As indicated, the virtual company is extreme in the sense that it has outsourced key functions such as purchasing, manufacturing, R&D, marketing and sales while keeping only the strategic management in-house. This means that the virtual company basically builds on an overall vision, a corporate strategy, a business strategy and a group of managers responsible for selecting the best-suited suppliers for the specific activities, and for coordinating the supplier network.

Galbraith (1995) argues that modern information technology facilitates the virtual company by allowing independent companies to join together in networks, which can
then act as if they were single corporations. Thus, Galbraith assumes that the rapid IT development will result in more virtual companies in the future. This assumption agrees with the findings of Hoek (1998) stating that “virtuality” in the international business seems to be developing at a fast pace. Hoek argues that logistics managers increasingly seem to focus their efforts on the development of information systems and software tools. One of the motives is to reduce inventories of finished goods by buying modules and only doing final assembly when the actual customer orders have been received (i.e. direct sale through the Internet and call centers).

2.6 Role of Sourcing Practices

Enterprises must adapt to market pressure and competitors' innovations with increasing speed to deliver both efficiency and effectiveness. From a combined business and functional strategy viewpoint, enterprises’ competitiveness and profitability call for improved organizational adaptability and more flexible and advanced systems (relative to manufacturing, logistics, engineering, information & process technology, etc.) to improve manufacturing efficiency and flexibilities.

There has been a growing recognition of the contribution of outsourcing to the attainment of competitive excellence and better potential to influence a firms’ flexibility in responding to market demands. More and more, the markets are witnessing a transformation, in which suppliers and customers are inextricably linked throughout the entire sequence of events that bring raw material from its source of supply, through different value-adding activities to the ultimate customer. Success is no longer measured by a single transaction; competition is, in many instances, evaluated as a network of co-operating companies competing with other firms along the entire supply chain. These changes are causing many industries to shift to strategic sourcing. Increasingly, supply chain integration and management are receiving a great deal of attention from researchers and practitioners alike and has been viewed as a viable initiative to enhance sustainable competitive advantage under the increased national and international competition.

Impact of sourcing in supply chain management (SCM) is a central and important area for academic research due to its impact on firms competing in today’s global economy, and is recognized as a contemporary concept that leads in achieving benefits of both operational and strategic nature (Al-Mudimigh et al., 2004). At the strategic level, it is a relatively new and rapidly expanding discipline that is transforming the way for improving
organizational competitiveness both in manufacturing and services (Gunasekran et al., 2004). The short-term objective is to increase productivity and reduce inventory and cycle time, while the long-term strategic goal is to increase customer satisfaction, market share and profits for all members of the virtual organization (Tan et al., 2002).

To realize these objectives, all strategic partners must recognize that the purchasing function, with its boundary-spanning activities, is a crucial link between the sources of supply and the organization itself (Wisner and Tan, 2000). Supplier segmentation appears to be an important concept of managing a company’s total supplier base in terms of inter-company performance and component criticality. Supplier segmentation appears to be an important concept of managing a company’s total supplier base in terms of inter-company performance and component criticality. Sourcing connects suppliers and buyers closely, which are two of the driving forces of competitiveness in an industry (Porter, 1980).

Oberoi and Khamba (2005a) aim to develop the buyer-supplier typology for strategic archetypes of contractual relationships. The typology reflects a buyer perspective ranging from arm’s length relationship to strategic partnerships and represents a supplier segmentation tool which helps identify what types of competence and capability relate to each individual sourcing practice, as they play a vital role in managing supply chain and described in the next section.

2.6.1 **Generic Sourcing Strategies**

Outsourcing takes place when an organization transfers the ownership of a business process to a supplier. The key to this definition is the aspect of transfer of control. This definition differentiates outsourcing from business relationships in which the buyer retains control of the process or, in other words, tells the supplier how to do the work (Narasimhan and Das, 1999). It is the transfer of ownership that defines outsourcing and often makes it such a challenging, painful process. In outsourcing, the buyer does not instruct the supplier how to perform its tasks, but, instead, focuses on communicating what results it wants to buy; it leaves the process of accomplishing those results to the supplier. Although outsourcing is playing a predominant role in today’s business environment, companies obviously have alternative sourcing strategies to consider. These sourcing strategies are largely determined by the companies’ position in the supply chain and sectoral pattern, and they all influence corporate identity (Fine and Whitney, 1996). The categorization of generic sourcing strategies based upon the level
of supplier involvement and new technology adoption in managing firm business competitiveness are formulated as:

- Make-or-Buy,
- Outsourcing,
- Insourcing
- Strategic sourcing

These strategic archetypes of contractual relationships differ widely with respect to the types of competence and capability they seek to access through the supplier network has been developed and shown in Table 2.5. Basically, the supplier knowledge contribution to the buyer increases along this continuum of relationships, which implies that, the level of collaborative integration and mutual investments peak in connection with strategic sourcing. In short, make-or-buy is defined as the cost-based decision to either produce commodity items in-house or purchase them from suppliers. Insourcing is defined as the “reverse” process of outsourcing. However, the motives of insourcing normally differ from those of outsourcing, with more focus on adoption of new technologies. In addition, insourcing does not necessarily involve a shift of ownership and decision rights, though this is the traditional view on the process.

Strategic sourcing is defined as the process of determining competencies provided by this supplier network contain a high degree of knowledge and are those most complementary to in-house core competencies. Hence, the company and the supplier share corporate incentives specific to their integrative collaboration. This broad definition describes two important aspects of outsourcing, both of which are often neglected in practice. One is the strategic dimension of outsourcing. This suggests that outsourcing is not only a matter of reducing or controlling operating costs, making capital funds available, accessing supplier capacity etc. It is also a matter of improving business focus, accessing world-class capabilities, accelerating re-engineering benefits, sharing risk etc. The other is the organizational restructuring in consequence of outsourcing. The company needs to carefully consider how to re-allocate personnel, machinery and materials when outsourcing makes former tasks superfluous.

The research perspective of strategic sourcing believes that: the competencies provided by the supplier network contain a high degree of knowledge and are those most complementary to in-house core competencies (including innovation in design and development).
### Table 2.5 Four strategic archetypes of contractual relationships (Oberoi and Khamba, 2005a)

<table>
<thead>
<tr>
<th>Sourcing Strategy</th>
<th>Make-or-buy</th>
<th>Outsourcing</th>
<th>Insourcing</th>
<th>Strategic sourcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Supplier</td>
<td>Component suppliers</td>
<td>Capacity Suppliers</td>
<td>Technology Suppliers</td>
<td>System Suppliers</td>
</tr>
</tbody>
</table>
| **Main motives**  | - Cost reduction  
- Access to residual competencies  
- Flexibility through capacity extension  
- Maximization of capacity utilization  
- Gains through economies of scale | - Focus on core competencies  
- Access to complementary competencies  
- Rationalization of internal organization  
- Multiple Production Criteria, e.g. lowered cost structure, shortened lead time and improved flexibility | - Focus on core competencies  
- Access to new technology  
- Stay in touch with technological innovations | - Joined knowledge contribution  
- Optimization of the value chain  
- Total quality management  
- Total cost perspective |
| **Key Characteristics** | - Focus on single transactions  
- Multiple sourcing  
- Separate resources  
- Self-sufficiency | - Relational competition  
- Process compatibility  
- Certification demands  
- Risk of losing touch with technology innovations | - Technology compatibility Joined asset specific investments  
- Technology development group | - Joined corporate incentives, investment and risk sharing  
- Dynamic policy of revision  
- Creation of synergy  
- Learn Supply |
| **Type of competence and capability** | - Purchased competence  
- Operational Capability  
- Flexibility capability | - Transferred competence  
- Knowledge transfer capability | - Supplied competence  
- Absorption capability | - Crossed competence  
- Relationship capability  
- Joined innovation capability |
| **Knowledge dependency** | Low | Medium | High | Very High |
| **Exchange of Information and IT applications** | - Very Limited  
- EDI/Fax/Email  
- Product and process registration  
- Material requirements planning(MRP) | - Restricted to the actual need  
- Internet/ Intranet/ Email  
- Manufacturing resource planning(MRP/I)  
- Enterprise resource planning(ERP) | - Daily Exchange of information  
- Internet/ Intranet/ Email  
- Manufacturing resource planning(MRP/I)  
- Enterprise resource planning(ERP) | - Open book principle  
- Internet/ Intranet/ Email  
- Supply chain planning systems |
| **Planning and control procedure** | - Master production schedule  
- Assembly scheduling and inventory status  
- Purchasing not fully integrated with manufacturing | - In house planning and control and control of purchasing and manufacturing  
- In house coordination of production demand and logistics | - In house planning and control and control of purchasing and manufacturing and technology  
- In house coordination of production demand and logistics | - Supply chain management  
- Joined development and strategic planning  
- Joined resource allocation |
| **Interaction approach** | Single interface | Transfer interface | Supply interface | Integrative interface |
| **Switching cost** | Low | Medium | High | Very High |
| **Time horizon of cooperation** | Short | Medium | Long | Very Long |
| **Appropriate governance structure** | Arm’s-length relationship | Proffered suppliers/ single sourcing | Network sourcing | Strategic partnership |
| **Learning process** | No “real” learning | From buyer to supplier(tutor) | From supplier to buyer(apprentice) | Mutual learning |
| **Managerial approach** | Reactive approach | Defensive approach | Analytic approach | Proactive approach |
| **Need for specifying product architectural knowledge** | Low | Medium | High | Very high |

- open architecture  
- semi-closed architecture  
- semi-closed architecture  
- closed architecture
In this study, from sourcing perspective, the impact of various facets of ‘outsourcing’ and ‘strategic sourcing’ have been mainly investigated for managing manufacturing flexibilities and termed as ‘sourcing practices’ or ‘supplier based sourcing practices’.

2.6.2 Supplier Segmentation

In consequence of the tendency to incorporate outsourcing or other sourcing strategies in the strategic planning process, the knowledge contribution from suppliers has increased, and some buyer-supplier relationships have become more close, intimate and long-term. However, the literature review suggests that many buyer-supplier relationships do not reach their full potential because of actions taken or not taken by the partners (Carter and Narasimhan, 1996; Krause et al., 2000; Narasimhan and Das, 1999; Simpson et al., 2002; Tan et al., 1999; Wisner and Tan, 2000). From a buyer perspective, however, the total supplier portfolio can advantageously be simplified to include four suppliers with four types of supplier that match the four sourcing strategies introduced in the preceding section.

These suppliers are:

- Component supplier (i.e. commodity items)
- Capacity supplier (i.e. non-strategic sub-systems)
- Technology supplier (i.e. innovative products or services)
- System supplier (i.e. strategic sub-systems)

The four profiles relate to make-or-buy, outsourcing, insourcing and strategic sourcing respectively. In short, the component supplier provides standard deliveries with low asset specificity, which means that the switching cost is relatively low. The capacity supplier provides fabrication parts, perhaps with engineering performance included. The technology supplier provides various products or services with a high degree of technological innovation. Finally, the system supplier provides sub-systems with high asset specificity, which means that the switching cost is relatively high. Typically, knowledge consultancy forms part of the scope of supply. The capacity/system suppliers play a cardinal role considering the scope of research. Collectively, these supplier profiles make up the extended supplier network of the company.

Some important implications of the four supplier profiles are worth noting. First of all, a company’s total supplier portfolio will probably consist of at least two of the supplier profiles (possibly all four) which must be incorporated in its overall supply strategy.
Secondly, the capacity suppliers and technology suppliers in particular might hold the potential to become system suppliers over time. That is, each supplier has a dynamic development perspective. The extended supplier network consists of legally independent entities used by the focal company (i.e. the buyer). The suppliers possess complementary competencies which are an extension to the company’s unique bundle of resources and capabilities. The four sourcing strategies and related implications synthesize the buyer-supplier typology, which reflects a buyer perspective. As it appears, the typology, Table 2.5, shows the match between the four sourcing strategies and the four supplier profiles. Thus, the typology represents a supplier segmentation tool which helps identify what types of competence and capability relate to each individual sourcing strategy. Furthermore, two inherent characteristics of the typology should be recalled. First, a company might make use of two or more of the sourcing strategies. Secondly, the capacity suppliers and technology suppliers in particular might hold the potential to become system suppliers over time. That is, the typology contains a dynamic development perspective.

2.6.3 Sourcing Practices and Supplier Selection

Supplier assessment and selection is designed to create and maintain such a network and to improve various supplier capabilities that are necessary for the buying organization to meet its increasing competitive challenges. A firm’s ability to produce a quality product at a reasonable cost and in a timely manner is heavily influenced by its suppliers’ capabilities, and supplier performance is considered one of the determining factors for the company’s success (Krause, 2000; Tan et al. 1998, Tan et al. 2002). Consequently, without a competent supplier network, a firm’s ability to compete effectively in the market can be hampered significantly.

There are several key reasons why suppliers are becoming increasingly critical to the competitive success. First, manufacturers are beginning to focus on their core competences and areas of technical expertise (i.e. firms concentrating on what they do best). An emphasis on internal competences requires greater reliance on external suppliers to support directly non-core requirement. Second, developing effective supply base management strategies can help counter the competitive pressures brought about by intense worldwide competition. To remain globally competitive, firms must receive competitive performance advantages from their suppliers that match or exceed the advantages that suppliers provide to leading foreign competitors. Third, suppliers can
support directly a firm’s ability to innovate in the critical areas of product and process technology. As organizations continue to seek performance improvements, they are reorganizing their supplier base and managing it as an extension of the firm’s business system. Given that over half the cost of goods sold worldwide is derived from purchased materials, supplier selection is an important strategic decision and serves as a source of competitive advantage (Pearson and Gritzmacher, 1990; Simpon et al. 2002).

Supplier selection becomes a central concern as the buyers look to form strategic partnerships. A growing emphasis on establishing long-term channel relationships, driven by competitive pressures and business complexity, has encouraged many firms to become highly selective in their choice of supplier. To build more effective relationships with suppliers, organizations are using supplier selection criteria to strengthen the selection process. Managers should focus on a set of supplier selection criteria that evaluates suppliers across multiple dimensions including product quality, product performance, and delivery reliability.

A comprehensive summarization of the literature related to the current state of-the-art of the survey-based empirical research on sourcing practices and supplier selection is shown in Table 2.6. It has been found that sourcing practices are recognized as a key contributor to firm’s success and can impact a firm’s competitiveness of low cost, high quality, reliable delivery, flexibility, and quick response time, which are also major dimensions of customer satisfaction.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Major Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watts and Hahn (1993)</td>
<td>Supplier development programs are more prevalent than expected and that large companies are more likely to be involved. The results also show the importance of formal supplier evaluation to the supplier development process.</td>
</tr>
<tr>
<td>Choi and Hartley (1996)</td>
<td>No differences among the auto assemblers, direct suppliers, and indirect suppliers were found for the importance placed on consistency (quality and delivery), reliability, relationship, flexibility, price, and service.</td>
</tr>
<tr>
<td>Narasimhan and Jayaram (1998)</td>
<td>This study examines the relationship among sourcing decisions, manufacturing goals, customer responsiveness, and manufacturing performance. An integrated supply chain involves aligning sourcing decisions to achieve manufacturing goals that are set to respond favorably to the needs of customers.</td>
</tr>
<tr>
<td>Tan, Handfield, and Krause (1998)</td>
<td>While many strategic quality approaches and supply base management tools are positively correlated with firm performance, quality management and supply base management techniques and tools must be implemented conjointly to achieve superior financial and business performance.</td>
</tr>
<tr>
<td>Reference</td>
<td>Summary</td>
</tr>
<tr>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>Carr and Pearson (1999)</td>
<td>Strategic purchasing is important to the success of the firm. Increased emphasis on strategic purchasing and supplier evaluation systems are critical for firms seeking to establish long-term relationships with their suppliers. Strategically managed long-term relationships with key suppliers can have a positive impact on the firm's financial performance.</td>
</tr>
<tr>
<td>Narasimhan and Das (1999)</td>
<td>Strategic sourcing can be used to target specific manufacturing flexibilities and that interflexibility synergies need to be considered while formulating flexibility-based manufacturing strategies.</td>
</tr>
<tr>
<td>Carr and Smeltzer (2000)</td>
<td>There is no statistical significance difference for type (manufacturing compared to non-manufacturing firms) and size (large compared to small firms) with respect to purchasing skills. Purchasing skills are related to strategic purchasing, a firm's financial performance, and supplier responsiveness.</td>
</tr>
<tr>
<td>Narasimhan and Das (2000)</td>
<td>Purchasing competence is found to have a positive impact on manufacturing cost, quality, and delivery, as well as new product introduction and customization performance. Purchasing integration, a component of purchasing competence, is found to relate to all dimensions of manufacturing performance.</td>
</tr>
<tr>
<td>Krsuse, Scannell, and Calantone (2000)</td>
<td>Direct involvement activities, where the buying firm internalizes a significant amount of the supplier development effort, play a critical role in performance improvement.</td>
</tr>
<tr>
<td>Tracey and Tan (2001)</td>
<td>Effective purchasing is an important element of supply chain management and a source of superior firm performance. Selecting and evaluating suppliers grounded in the criteria of quality, delivery reliability, and product performance enhances the four dimensions of customer satisfaction (price, quality, flexibility, and delivery) and firm performance.</td>
</tr>
<tr>
<td>Carr &amp; Pearson (2002)</td>
<td>Purchasing/supplier involvement has a positive impact on strategic purchasing, and strategic purchasing has a positive impact on firm's financial performance.</td>
</tr>
<tr>
<td>Tan (2002)</td>
<td>This study investigates the contemporary practices and concerns of supply chain management, also relates the practices and concerns to firms' performance. A general conclusion is that all of the significant supply chain management practices positively impact performance.</td>
</tr>
<tr>
<td>Tan, Lyman, and Wisner (2002)</td>
<td>This study revealed that supply chain management practices could be categorized into six constructs and supplier evaluation practices could be categorized into three constructs. Some of the constructs identified in this study correlated positively with firm performance.</td>
</tr>
<tr>
<td>Rozemeijer, Weele, and Weggeman (2003)</td>
<td>Corporate purchasing initiatives should be congruent with the overall level of corporate coherence and the level of maturity of the purchasing function.</td>
</tr>
<tr>
<td>Modi and Mabert (2007)</td>
<td>Evaluation and certification efforts are the most important supplier selection and development prerequisites before undertaking operational knowledge transfer activities such as site visits and supplier training.</td>
</tr>
</tbody>
</table>
2.6.4 **Supplier Selection and Manufacturing Flexibility**

The supplier selection strategy in terms of technology, quality, cost, flexibility and delivery performance are important strategies in overcoming the “upstream” uncertainties, such as supplier defaults on delivery and performance, high cost production, and quality rejects; as well as “downstream” uncertainties due to demand volatility and changes in product mix, price, and competition action, which requires flexibility in the manufacturing processes.

Vonderembse and Tracey (1999) found that although both the supplier selection criteria and the supplier involvement are positively correlated with manufacturing performance, the supplier involvement in product design activities and continuous improvement efforts is much lower than the use of supplier selection criteria. Early supplier involvement has an even greater benefit, a shortening of design cycle time, which means faster launch flexibility. However, there is lack of literature, which relates directly this strategy and the manufacturing flexibility.

Jantan et al. (2005) examine the impact of supplier selection and management strategies on manufacturing flexibility (such as product flexibility, launch flexibility, and volume flexibility). They find selection of supplier based on technology is important for the manufacturer focus on product and launch flexibility. However, quality becomes strategically important when the manufacturer is focusing on volume flexibility. Inventory management and technology roadmap are very important supplier management strategies with robust influence on all three forms of manufacturing flexibilities, namely product flexibility, launch flexibility, and volume flexibility. Lastly, the study has shown that there is no single formula that can fit all situations. It depends on the performance measures, business nature, business environment and other market factors that the manufacturer needs to deal with. The manufacturer needs to understand clearly which flexibility of its operation is required, and then adopt a working supplier selection and management strategy.

Kayis and Kara (2005) study analyses how customer-supplier relationship could have an impact on manufacturing flexibility and enhances the total chain of manufacturing. As the different elements under flexibility have suggested, the manufacturing flexibility of Australian industries as affected by customer-supplier participation is medium and some of the guidelines for pursuing improvement is recommended below:
- Giving more attention to the demand for variation in the products from customers in the set up of manufacturing objectives enabling industries to become more flexible to respond and keep in mind of the changing in demand of customers.
- Acknowledging the concept of fewer suppliers where long-term relationships could be formed and constantly cherished.
- Getting more involvement from the customers, especially in terms of product and process design, where things could be allocated and designed correctly from the start, making the system more flexible for any other subsequent changes.
- Planning and coordination of all suppliers and customers from the planning stage by establishing plans to ensure well established relationship as well as collaboration.

2.7 Development of Conceptual Framework

Based upon the examination of the literature review and scope of the present research, a conceptual framework has been derived and presented in figure 2.2 for explicating the complexities involved in managing manufacturing flexibility at firm level, and their linkages with advanced manufacturing technology and sourcing practices in manufacturing industry. It is proposed to focus on three dimensions of manufacturing flexibility—volume flexibility, modification flexibility and delivery flexibility. It is hypothesized that sourcing practices and advanced manufacturing technology will influence these three flexibility dimensions positively. Further, it is hypothesized that different sourcing practices and advanced manufacturing technology have a positive associations with different aspects of manufacturing flexibilities.

![Figure 2.2 A conceptual framework showing the interlinkages between flexibility, technology and sourcing aspects.](image)
The primary interest in data analysis is to investigate the influence of new technology and sourcing practices on manufacturing flexibility. The empirical examination of the conceptual framework therefore, focused on the understanding and explication of the interaction between advanced manufacturing technology, sourcing practices and manufacturing flexibilities and assesses their relative impact on different flexibilities. Since operational level flexibilities are primarily equipment driven and occur at the shop-floor level, it is unlikely that sourcing will have a major impact on flexibility at this level. Tactical and strategic flexibilities, such as volume, modification and delivery flexibilities appear at the plant or firm levels. Suppliers interface with their customers at the plant or firm level. Hence, it is more likely that sourcing will influence these dimensions of manufacturing flexibility. Also, as Slack (1990) confirms, tactical and strategic level flexibilities matter more to managers than lower level operational flexibilities. There is some evidence in the literature that sourcing can influence modification, volume and new product flexibilities (Olhager 1993, Suarez et al. 1996). These flexibilities occur at the tactical and strategic level and the impact of sourcing practices is most readily perceived at these levels (Gerwin 1987).

The framework depicts that, in a dynamic business environment, organizations have to manage the manufacturing flexibility needs effectively through the systematic implementation of business strategy, including the use of advanced manufacturing technology and sourcing practices. Attainment of manufacturing flexibility further facilitates the realization of varied business performances in terms of manufacturing, design, flexibility and execution competencies. These competencies are a measure of a firm’s ability to flexibly deploy resources to support its business strategy, develop a responsive production systems, covert its flexibility (and other manufacturing) capabilities into tangible, firm-level performance outcomes and enables firms to perform at high levels for building business competitiveness.

2.8 Limitations of Existing Approaches

This chapter reviews the previous studies on concept of flexibility, critique and taxonomy of manufacturing flexibilities, advanced manufacturing technology, sourcing practices and their relationships. The literature has also been reviewed on methodologies to be used in carrying out the research.

The review of past literature indicates sufficient gaps for the conduct of such study.
• The role of sourcing practices and technology on different manufacturing flexibilities have been individually addressed in the literature, but there are hardly remote cases available which reports the relative impact of these practices on different manufacturing flexibilities.

• It is clear that sourcing has the potential to influence an organization’s flexibility in responding to market demands. What is not known is exactly which aspects of flexibility performance are affected by sourcing actions, and how these flexibilities, once attained, influence manufacturing performance.

• Multidimensionality of flexibility tangles the effort that must go into creating and testing scales and collecting data.

This research intends to bridge those gaps in literature and practices by suggesting a systematic plan for achieving different manufacturing flexibilities through trade off associated with the use of advanced manufacturing technology and sourcing practices in the Indian manufacturing industry.

2.9 Concluding Remarks

A selective review of available literature in the field brings out a numerous points relating to manufacturing flexibility, advanced manufacturing technology and sourcing practices in a logical manner and their interrelationships. Based upon the literature review a taxonomy and definition of manufacturing flexibility has also been derived and presented in this chapter. Further, systematic strategic archetypes of contractual relationships have been outlined and presented for categorizing the different sourcing practices and supplier segmentation. A conceptual framework has finally been developed and presented to understand the linkages between business strategy and manufacturing flexibility. Next chapter introduces overall design of study, which includes phases of research and the methodology adopted for carrying out the research work.